EVALUATION OF ENVIRONMENTAL MANAGEMENT COST-ESTIMATING CAPABILITIES for MAJOR DEFENSE ACQUISITION PROGRAMS

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This report is the final product from the Survey of Resources Available for Estimating the Environmental Costs of Major Defense Acquisition Programs. It provides assessments of the most promising cost analysis tools based on testing their capabilities against the cost breakdown structure developed earlier in the project. The most substantial reviews cover HAZMAT, HCAS, MCACES, and RACER-ENVEST. In addition, the report includes reviews of one or two pages for 23 technical reports with some value for environmental cost estimating. Finally, building on the foundation of these assessments, the report lays out short- and mid-term plans for filling gaps in the tool set.

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EXECUTIVE SUMMARY

The Chairman of the Cost Analysis Improvement Group, under the Office of the Secretary of Defense, has initiated an effort to ensure that the cost of protecting or restoring the environment is reflected in the life-cycle cost (LCC) estimates presented to the Defense Acquisition Board. A project to improve the ability of cost analysts, project engineers, program managers, and others to assess the cost impact of environmental conditions on Major Defense Acquisition Program (MDAP) LCC estimates and to make design decisions recognizing these environmental cost impacts is part of the Chairman's initiative.

The Project Team conducted a comprehensive survey to identify, classify, and evaluate environmental management (EM) cost-estimating and -analysis tools. EM, as defined in this report, is the management of hazardous, toxic, and radiological (HTR) substances throughout the life cycle of an MDAP. The EM Cost Breakdown Structure (CBS) comprises five major categories of work: Environmental Program Management, HTR Material Management, HTR Waste Management, Environmental Restoration/Corrective Action, and HTR Material and Waste Transportation.

Identifying and classifying EM cost-estimating and -analysis tools was the first phase of the project. The results are presented in the *Environmental Management Tool Screening Report*. For the second phase, the Team developed both the hierarchical CBS of EM activities and the Cost Driver Category (CDC) in order to have a meaningful, standard measure against which to assess the range and depth of coverage provided by EM cost-estimating tools. The *Environmental Management Category Report* defines the activity-based EM CBS and the associated CDC.

For the third phase of the project, the Project Team evaluated tools (selected from those identified during the first phase) to assess the range and depth of coverage these tools have with respect to the EM CBS and CDC (established in the second phase), and determined their relevance to MDAP LCC estimating. The composite set of EM cost tools was evaluated to assess the overall coverage and to determine areas requiring further development. Based on the composite analysis, the Project Team developed a Short-Term Plan to modify existing tools and a Long-Term Plan to develop additional tools. The evaluations and both the Short- and Long-Term Plans are presented in this report.

The CBS activities most relevant to the MDAP LCC are CBS 1.0 Environmental Program Management, CBS 2.0 HTR Material Management, and CBS 3.0 HTR Waste Management. These are most relevant because:

- These activities represent the majority of environmental cost associated with the life-cycle phases (i.e., Development, Production, Operations & Support, and Decommissioning & Disposal) of an MDAP.

- The sooner in the manufacturing and maintenance processes that alternative environmental practices can be employed, the greater the impact on the LCC. Conversely, costly environmental compliance and restoration activities may be required if EM practices are inadequate.

The results of the evaluation show that the most relevant CBS activities are substantially less well covered by the cost tools than are the Environmental Restoration/Corrective Measures and HTR Material and Waste Transportation activities. The Team identified two models in the cost tool survey that address HTR Material Management. One is the Hazardous Materials Life Cycle Estimator (HAZMAT) model developed by the Air Force. HAZMAT is based on the costs for the manufacturing and maintenance process operations for eight weapon systems. For reasons discussed in the HAZMAT Evaluation sections (7.2.1–7.2.7) of this report, this model is difficult—and probably impractical—to use to estimate weapon-system-level environmental cost. HAZMAT, however, is useful in conducting pollution-prevention trade-off studies. The second model identified is the Navy-developed Hazardous Material Life-Cycle Cost Model. As discussed in section 5.2, this model does not add to the estimating capability provided by HAZMAT.

The System Cost Model (SCM), developed by the U.S. Department of Energy, is the only model identified in the cost tool survey that addresses HTR Waste Management. However, because this model addresses the treatment, storage, and disposal of only radiological waste, it does not apply to MDAPs.

In theory, the CBS elements associated with the Environmental Restoration/Corrective Measures activity are the least relevant to MDAPs because all (manufacturing and maintenance) facilities will remain in compliance. In reality, this is not the case. This project, therefore, recognizes that the cost of clean-up may need to be estimated. Environmental Restoration/Corrective Measures costs are thoroughly addressed by existing cost tools, particularly the following:

- Historical Cost Analysis System, a historical project cost database
- Remedial Action Cost Estimating System, a parametric cost estimating model
- Microcomputer-Aided Cost Engineering Support System, a bottoms-up estimating system.

These environmental restoration (ER) tools are an example of a complete estimating system that may serve as the prototype of a complete EM cost-estimating system. The Short-Term and Long-Term Plans presented in chapter 6 discuss the potential for using this prototype system to develop similar capabilities for the other CBS elements.

The Short-Term Plan is a "quick-fix" approach designed to fill the gaps in the collective set of cost tool capabilities. The approach includes modifying selected tools and identifies engineering case studies and reports to supplement the cost models and databases. The Long-

Term Plan discusses cost-tool development required to provide an adequate set of tools for cost professionals to include EM costs in the MDAP LCC.

In addition to assessing the utility of the cost tools in developing EM estimating capabilities, the Short-Term and Long-Term Plans suggest:

- Making specific modifications to the HAZMAT model to increase its estimating capabilities
- Developing a version of the SCM that addresses hazardous waste streams
- Using specific engineering case studies and reports
- Conducting comprehensive, relevant EM cost estimates/trade-off studies to support an on-going MDAP LCC estimate
- Developing a data-collection strategy
- Developing a comprehensive EM cost-estimating and -evaluation system to include all CBS elements.

1 INTRODUCTION

The Chairman of the Cost Analysis Improvement Group, under the Office of the Secretary of Defense, initiated an effort to ensure that the cost of protecting or restoring the environment is reflected in the life-cycle cost (LCC) estimates presented to the Defense Acquisition Board (DAB). This initiative includes identifying, classifying, and critically evaluating cost-estimating models, cost databases, engineering case studies, and other analytical tools to determine the existing environmental management (EM) cost-estimating and -analysis capabilities and to develop plans to improve these capabilities. The set of identified and developed analytical tools will be useful to cost analysts, project engineers, program managers, and others who assess the cost impact of environmental conditions on Major Defense Acquisition Program (MDAP) LCC estimates and make design decisions based on those environmental cost impacts.

This document reports the results of an evaluation of selected EM cost-estimating tools. The tools were identified and selected through a survey conducted as the first phase of the project. The survey process and results are in the *Environmental Management Tool Screening Report.*[1] The following chapter, EM Cost Tool Evaluation Methodology, summarizes the first phase of this project. The cost tools identified in the first phase were evaluated against a matrix comprising EM cost categories that were defined in the second phase. The EM cost-category development process and definitions are in the *Environmental Management Category Report*[2] and are summarized in Chapter 3 CBS/CDC Development/ Definition. The remaining chapters in this document contain the Cost Tool Evaluation Matrix (chapter 4), Aggregate Cost Tool Evaluation (chapter 5), Short-Term/Long-Term Plans (chapter 6), Cost Database/Model Tool Evaluations (chapter 7), and Evaluations of Cost-Estimating Reports (chapter 8).

This report summarizes the *Tool Screening Report* and the *Environmental Management Category Report* and provides a comprehensive analysis of existing models, databases, case studies, and reports; identifies current EM cost-estimating and analysis capabilities; and provides a foundation for further research and analysis to address environmental costs associated with MDAPs.

[1]*Environmental Management Tool Screening Report for the Survey of Resources Available for Estimating the Environmental Costs of Major Defense Acquisition Programs.* [Prepared by CAPSTONE Corporation, Alexandria, Virginia, for the Office of the Secretary of Defense (PA&E)], July 29, 1994.(AD #A285363)

[2]*Environmental Management Category Report for the Survey of Resources Available for Estimating the Environmental Costs of Major Defense Acquisition Programs.* [Prepared by CAPSTONE Corporation, Alexandria, Virginia, for the Office of the Secretary of Defense (PA&E)], August 30, 1994. (AD #A285431)

2 EM COST TOOL EVALUATION METHODOLOGY

This chapter explains how the cost tool survey was conducted, how the CBS and CDC were developed, how the cost tool evaluations were performed, and how the associated Short-Term and Long-Term Plans were developed.

Two of the principal problems facing an environmental cost estimator/analyst are the lack of historical cost data and inconsistent definitions of environmental activities. The first questions that need to be asked in performing a cost estimate or cost analysis are:

- What tools exist to estimate EM LCC—from pollution prevention and compliance programs through disposal of the weapon system and possible closure of associated facilities?

- What are the elements of work associated with EM costs?

- What elements of environmental costs are not covered (or inadequately covered) by the existing set of EM cost-estimating tools?

This project was designed to answer these questions. The Project Team conducted a comprehensive survey of EM cost-estimating tools to answer the first question. The results of the survey are provided in the *Environmental Management Tool Screening Report.*

Specifically, the Project Team conducted a literature search of Department of Defense (DoD), Department of Energy (DOE), Environmental Protection Agency (EPA), and industry sources. The search identified some 190 potential cost-estimating tools. These tools were screened to determine if they addressed EM and were available for public distribution. Those which did not meet both screening criteria were eliminated from further consideration. This first screening left 71 tools. The Project Team placed each of the remaining tools in one of the following classifications:

- Classification 1: Unit-Cost Models and Databases
- Classification 2: Parametric Cost Models
- Classification 3: Project Cost Databases
- Classification 4: Engineering Case Studies and Reports
- Classification 5: Project Management Systems
- Classification 6: Application Software Platforms.

The classification into which a tool was placed served as the criterion for the second screening. The *Environmental Management Tool Screening Report* defines each of these classifications and delineates which tools fall into them. The second screening eliminated project management systems (classification 5) because these systems offer little or no content specific to environmental cost estimating. Application software platforms (classification 6) also were eliminated because they provide only templates and do not include unit-cost data or

cost-estimating relationships. The 49 remaining tools included 10 cost models (classification 1 and classification 2), 2 databases (classification 3), and 37 engineering case studies and reports (classification 4). These were the tools initially considered for analysis and inclusion in this document.

Of the 12 cost models and databases, 5 were screened out because the equations, algorithms, and/or databases were not made available to the Project Team. The remaining cost models and databases were selected for further evaluation. They are:

- Micro-Computer Aided Cost Engineering Support System (MCACES)
- Hazardous Material Life Cycle Cost Estimator (HAZMAT)
- Remedial Action Cost Engineering and Requirements (RACER)
- Superfund Cost Estimating Expert System (SCEES)
- System Cost Model (SCM)
- Decontamination and Decommissioning (D&D) Database
- Historical Cost Analysis System (HCAS).

After an initial evaluation of these seven cost models and databases, three—SCEES, SCM, and D&D—were eliminated from further consideration.

- SCEES addresses only the Remedial Investigation/Feasibility Study (RI/FS) subelement of the ER CBS element. RACER, however, was developed with benefit of the SCEES model and provides the cost analyst with greater estimating capability for RI/FS and also includes many other ER CBS elements. Because SCEES offers nothing that is not included in the more recently developed RACER, the Project Team selected RACER for evaluation.

- The current version of SCM addresses only radiological waste streams and is designed to address only specific DOE sites.

- The D&D model is under development and is not yet ready for release. The Project Team was, therefore, unable to acquire a copy of it.

Of the original 37 engineering case studies and reports, 8 were not available; however 2 new reports were added.

To perform an objective, consistent, and thorough evaluation of the selected environmental cost tools the Project Team developed a comprehensive structure of EM activities and cost drivers. This two-part structure includes the entire life cycle of EM activities associated with manufacturing and maintenance processes, as well as, ER (or clean-up) activities. The activity-based portion of the structure is the CBS; the portion of the structure containing cost drivers is the CDC. To develop theses structures, the Project Team visited DoD installations and depot facilities to ensure that all current EM activities were identified. Other sources of information included cost element structures from DoD, DOE, and the Interagency Cost Estimating Group (ICEG).

Chapter 3 describes both the CBS and CDC and how they relate to a regulatory-based structure and how they fit into the MDAP life-cycle phases (i.e., Demonstration/Validation, Development/Production, Operations & Support, Decommissioning/Disposal).

The Project Team evaluated each of the environmental cost tools to determine its range and depth of coverage according to the CBS. The range is a measure of the number of first- or second-level CBS elements addressed. The depth is a measure of the number of subordinate CBS elements addressed. The Project Team evaluated cost tools to determine their coverage of the CDC. The method used to perform these evaluations is presented in Chapter 4 Cost Tool Evaluation Matrix.

The Project Team also evaluated:

- Each tool from a user's perspective
- Key attributes of the cost models and databases to determine the appropriate usage
- Analytical flexibility of the cost models to determine the extent to which it can be customized to meet site-specific conditions and accommodate site-specific information
- Cost tools' bases, rationales, and methodologies.

These evaluations are presented in the chapter 7.

Chapter 5 Aggregate Cost Tool Evaluation shows the overall CBS coverage of the composite set of tools. Chapter 5 also discusses the use of this set of estimating tools for MDAP LCC estimating and for trade-off studies. The summary matrix (figures 5-1, 5-2, and 5-3) identifies weak or missing areas of estimating capability; both a Short-Term Plan and a Long-Term Plan for obtaining capabilities in the identified areas are presented in chapter 6.

The Short-Term Plan is a "quick-fix" approach to fill the cost-estimating gaps. It suggests modification of selected tools and recommends the use of selected engineering case studies and reports to supplement the cost model and databases. The Long-Term Plan addresses the need to develop an adequate set of tools, develop verification and/or validation plans for those tools, and maintain those tools.

3 CBS/CDC DEVELOPMENT/DEFINITION

The CBS and CDC provide an important perspective on environmental activities associated with MDAP life-cycle phases and their associated cost drivers. The Project Team developed the CBS/CDC structure to provide a means to measure the range and depth of coverage of EM cost tools. But the structure also provides a framework with which to communicate environmental conditions within the engineering and cost communities.

To establish this communications framework, two primary questions were addressed: What does EM include? How does EM apply to the LCC of an MDAP?

3.1 WHAT DOES ENVIRONMENTAL MANAGEMENT INCLUDE?

EM, as it applies to MDAPs, is the management of activities, processes, and products that can or do impact on the environment. This impact can take different forms, including the following:

- Energy releases
  - Electromagnetic forces
  - Ionizing radiation
  - Noise
  - Excess heat
- Substance releases to air, water, or land
  - Non-hazardous substances
  - Hazardous/toxic substances
  - Ozone-depleting compounds (ODCs)
  - Radiological substances
- Physical disruption of natural habitats
  - Facility construction
  - Land development (e.g., clearing, excavation, irrigation)
  - Water diversion.

Impacts to the environment can be shown by degradation of, or disruption to, the following:

- Ecosystems
- Endangered species
- Cultural and archeological resources
- Human health.

Managing such impacts and their associated costs is accomplished through these environmental programs:

- Pollution prevention
- Compliance
- Conservation
- Cleanup.

3.2 HOW DOES EM APPLY TO MDAP LCC?

In April 1994, a workshop on Environmental Life Cycle Cost Estimating for Weapon Systems convened to address the question of how EM applied to the MDAP LCC. Participants in the workshop included representatives from the DoD, other Government agencies, the regulatory community, and industry. Consultants and academics also participated. The result of this workshop was the advent of the Environmental Cost Element Structure (ECES), which provides a foundation for defining EM costs in relation to a weapon system's work breakdown structure (WBS) defined in MIL-STD-881B. This structure is based on how the programs deal with environmental regulatory requirements (i.e., pollution prevention, compliance, conservation, and cleanup).

The ECES is regulatory-based rather than activity-based. Therefore, it did not provide the Project Team with the means to measure the range and depth of EM cost-tool coverage. To perform the EM cost tool evaluations, the Team developed the CBS and CDC to provide a framework of activities and environmental factors.

The CBS/CDC focuses on only those EM activities that deal with hazardous, toxic, and radiological (HTR) materials—including ODCs—and waste management. The CBS is a framework of EM activities (broken down into elements of work) associated with HTR materials and wastes. The activities are:

- CBS 1.0 Environmental Program Management (e.g., environmental program planning, compliance management)

- CBS 2.0 HTR Material Management (e.g., HTR procurement, distribution, control)

- CBS 3.0 HTR Waste Management (e.g., HTR waste treatment, storage, disposal)

- CBS 4.0 Environmental Restoration/Corrective Measures (e.g., site discovery, site assessment, cleanup)

- CBS 5.0 HTR Material and Waste Transportation.

The CBS applies to each phase of the MDAP's life cycle although the portion of the CBS that is applicable will change depending on the phase of the life cycle. For example, HTR Material Management (CBS 2.0) is of primary concern during the Development/Production

and Operations & Support life-cycle phases, whereas Environmental Restoration/Corrective Action (CBS 4.0) is of primary concern during the Decommissioning phase.

Figure 3-1 shows the integrated nature of EM activities in the MDAP's life-cycle phases. This figure emphasizes the relationship of facility process flow to the MDAP's life-cycle phases. There are several facility types (e.g., manufacturing, maintenance) associated with the MDAP's life-cycle phases, and they are often not dedicated to the subject MDAP. This situation makes the development of a generic cost model difficult because the facility business base and other facility-specific considerations (e.g., allocation of facility cost to the subject MDAP, facility overhead) can greatly affect the cost estimate. This condition is discussed in the HAZMAT evaluation presented in the chapter 7. Figure 3-1 also illustrates the integral, often inseparable, and highly iterative relationship between the EM process flows and the facilities' Manufacturing/ Maintenance process flow. The CBS defines the activities associated with the Environmental Management box in figure 3-1.

Figure 3-2 is essentially an expansion of the Environmental Management Process Operations box in figure 3-1, but figure 3-2 also includes the life-cycle of the facility itself. That is, the decision box that asks the question, "Is Site in Compliance?" refers to the end of the facility's useful life. The closure of a facility under the provisions of the Resource Conservation and Recovery Act (RCRA) may or may not be considered part of the MDAP's LCC depending on the situation. For example, if a facility is built solely to support an MDAP, the facility RCRA closure cost should be included in the MDAP LCC estimate.

Figure 3-2 shows all facility environmental activities whether or not the costs for the activities are direct and separable. Direct costs are those that are attributable to environmental tasks. An example of a direct cost is the cost for protective clothing. An indirect cost is one that is not directly attributable to environmental activities. For example, costs for fire and security services are (generally) shared (i.e., they are not separated) by all facility missions. The cost accounting for these activities is different for each facility involved in the MDAP. Therefore, the definition of those activities considered direct or indirect will vary. A generic cost model must clearly document its assumptions regarding the treatment of these activities.

The CBS and CDC dictionaries are in appendix A. It should be noted here that changes have been made to the CBS and CDC dictionary since they appeared in the *Environmental Management Category Report*. The only significant changes are:

- CBS 3.0 HTR Waste Management: The facility closure subelement was promoted from the third level to the second level.

- CDC D.0 Mode of Transportation: This element has been eliminated as a cost driver category and added as lower-level activities under CBS 5.0 HTR Materials and Waste Transportation.

The CDC is organized by major cost drivers and considerations associated with EM that significantly influence (or that can significantly influence) an MDAP's LCC. The Project Team used the CDC in conjunction with the CBS to develop the Cost Tool Evaluation

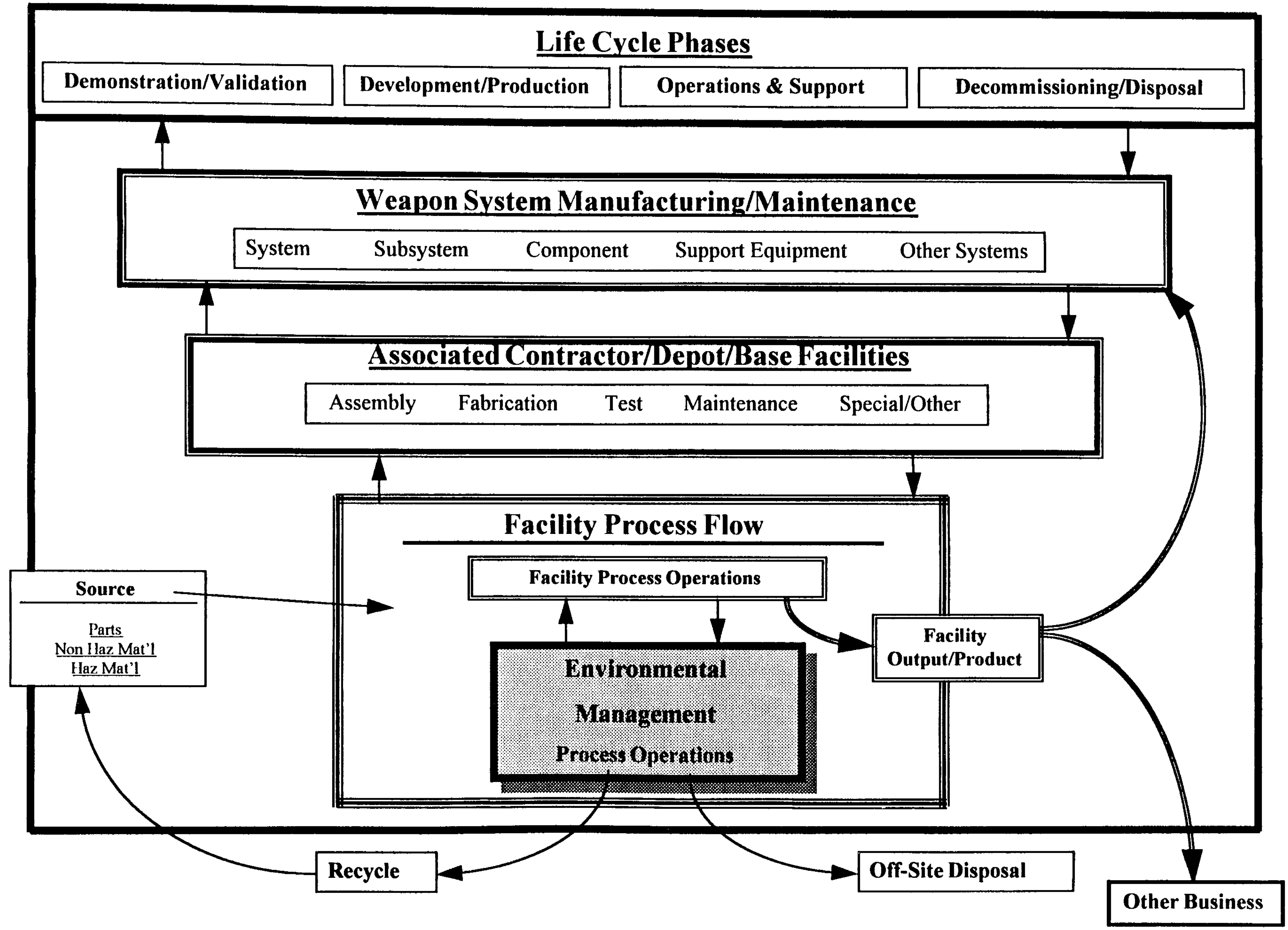

FIGURE 3-1.—MDAP Life-Cycle Process Flow

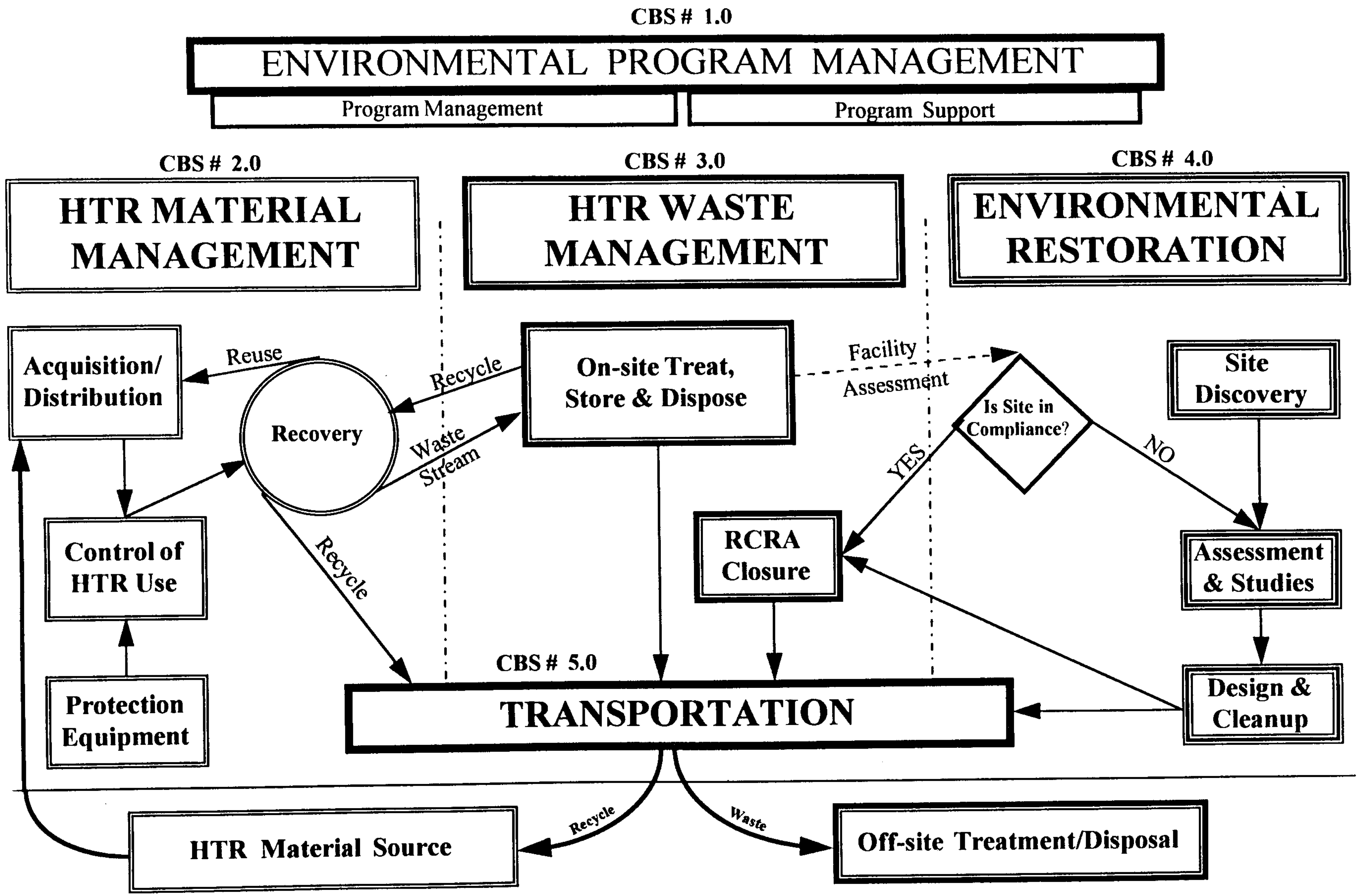

FIGURE 3-2.—Environmental Management Life-Cycle Process Flow

Matrix. While the CBS defines the activities associated with EM, the CDC incorporates other important factors that affect the cost of EM activities. For example, the HTR Material Management activities associated with a highly toxic substance, such as PCB, will be more costly than those for a less toxic substance. In addition to greater cost for these activities, the potential for incurring other costs due to medical and liability risks is increased. The CDC factors are:

- CDC A.0 Hazardous, Toxic, and Radiological Substances (e.g., HTR flammable, corrosive, low-level mixed radiological materials/waste)
- CDC B.0 HTR Waste Sources (e.g., process waste streams, ER landfills)
- CDC C.0 Personnel Protection Levels (e.g., standard work clothing, positive-pressure breathing apparatus)
- CDC D.0 Environmental Management Cost Risk (e.g., medical risk, liability damages risk).

4 COST TOOL EVALUATION MATRIX

The Project Team performed a detailed analysis of each EM cost tool to determine its range and depth of coverage of the CBS/CDC. To accomplish these analyses, a detailed evaluation matrix was developed using the CBS and CDC. A portion of the HAZMAT model's Detailed Evaluation Matrix for CBS 2.01 (HTR Material Management and Support) is shown in figure 4-1. The first set of columns with the headings "CBS Depth Score" represent the CBS levels. The remaining column heading are the CDC elements. See the CDC listing included in appendix B for the elements represented by the numbers.

A cost tool's range of coverage is the number of highlighted (shaded) CBS elements addressed by the tool. CBS elements are highlighted at different levels of the CBS according to the relative importance of the element from an MDAP LCC perspective. For example, the CBS is highlighted at the second level for CBS 1.0 Environmental Program Management and at the third level for CBS 2.0 HTR Material Management. The Project Team determined that the greater visibility of some CBS elements is required to appropriately measure a cost tool's capabilities.

A cost tool's depth of coverage is the percentage of subordinate elements of a given CBS element addressed. As shown in figure 4-1, the highlighted elements under CBS 2.01 HTR Material Management and Support are CBS 2.01.01 Pollution Prevention Program Implementation and CBS 2.01.02 Compliance Program Implementation. This figure shows that the HAZMAT model does not specifically address any of the elements subordinate to CBS 2.01.01 but does address 50% of the elements subordinate to CBS 2.01.02.

The CDC elements are considered only for each highlighted CBS element. The implication here is that the same CDC elements apply to all subordinate CBS elements. To develop the Detailed Evaluation Matrix, the Project Team determined the applicability of each CDC element to each CBS element. If it was determined that the CDC does not (or is unlikely to) apply to the given CBS element, the associated matrix cell is blank. An example of the rationale used to make these determinations, is provided below. The CDC applicability determination for CBS 2.01.01 is:

- CDC A.0 Hazardous/Toxic and Radiological Substances is applicable. The HTR material studies are directly related to the type of substance.

- CDC B.1 Waste Sources—Manufacturing, Operational Bases, and Depot Facilities is applicable. This CBS element can be affected by the sources of waste due to variation in facility type and capacity to handle the waste stream.

- CDC B.2 Waste Sources—Environmental Restoration is not applicable. All EM activities associated with ER are accounted for in CBS 1.0 and 4.0.

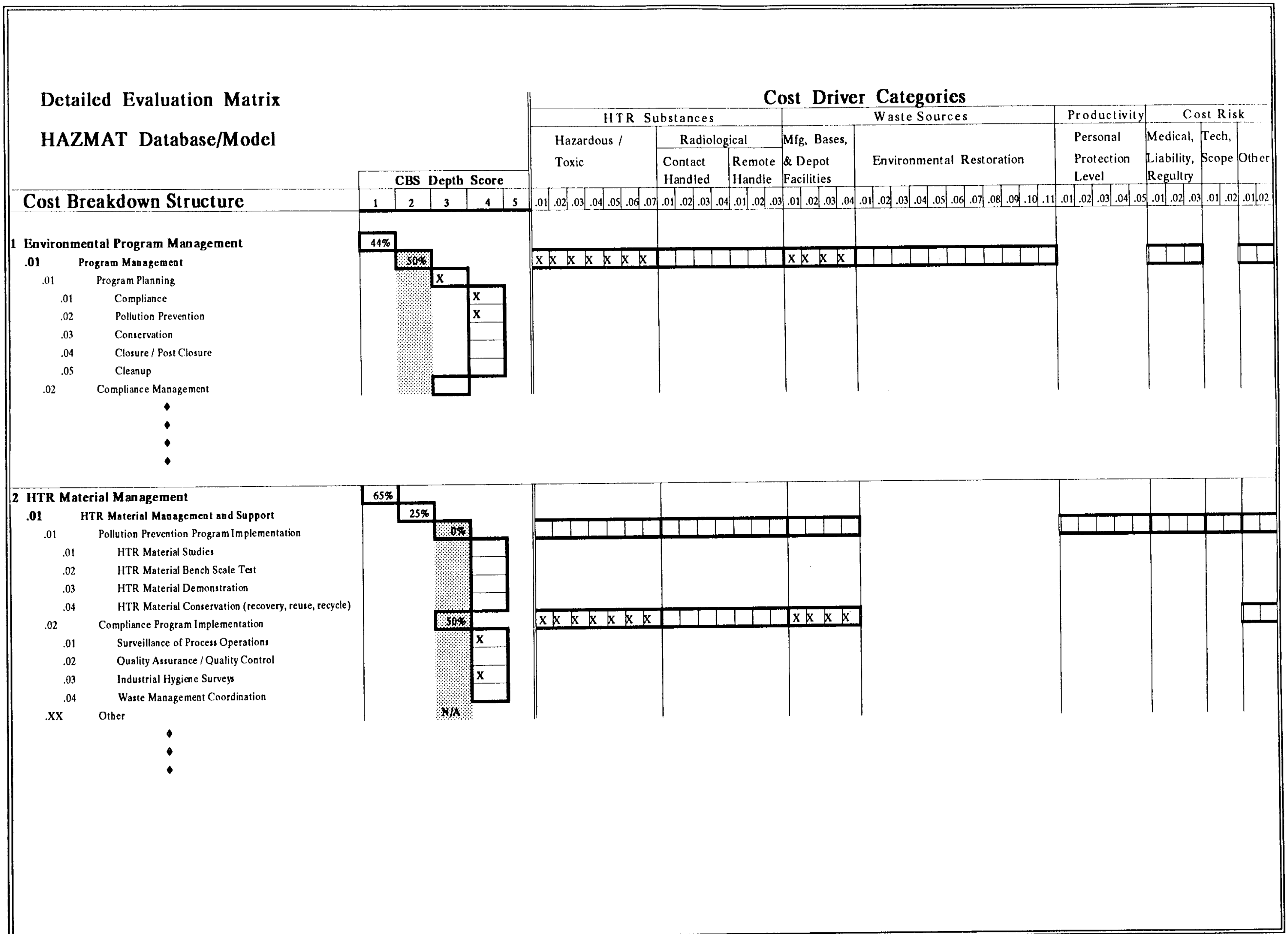

FIGURE 4-1.—Excerpt from the HAZMAT Database/Model Detailed Evaluation Matrix

- CDC C.0 Productivity-Personal Protection Level is applicable. Workers who may come into contact with HTR material require protection.

- CDC D.1-3 Cost Risk—Medical Risk, Liability Damages Risk, and Regulatory Risk is applicable. Medical risk is possible because of worker exposure to HTR substances. Liability risk is possible because toxic torts may be brought. Regulatory risk is possible because more stringent requirements for HTR material tests may be imposed.

- CDC D.4-5 Cost Risk—Technical Risk and Scope Risk is applicable. Technical and scope risks are possible due to the uncertainty of material test outcomes.

- CDC D.6 Other Risk—Cost Ranges and Unknown is applicable. Cost ranges are applicable to all CBS elements because variances can occur for any activity. Similarly, there is a possibility of unidentifiable or unknown cost risk associated with all activities.

The coverage of the CDC by the HAZMAT model is indicated by an X in the applicable evaluation matrix cells as shown in figure 4-1.

To communicate the results of the detailed analyses, a summary evaluation matrix was developed. A portion of the summary level HAZMAT Evaluation Matrix is presented in figure 4-2.

The CBS depth score is a measure of the extent to which the model addresses the CBS element. This score is calculated from the percentage of subordinate elements addressed in the highlighted CBS elements in the associated Detailed Evaluation Matrix. The CBS legend shows the score calculated from the subject percentage.

The Project Team determined the degree to which the tool addressed each CDC element. The CDC legend of the summary-level matrix indicates the three possible degrees as follows:

- If the Project Team determined that the model (or database) does not include the cost driver then an empty box is shown.

- If the model addresses the cost driver at a higher level than the subject CBS element or if it addresses the cost driver by implication (i.e., the documentation states that the cost is included although it is not specifically called out in equations), then a sparsely filled (filled with / / /) box is shown.

- If the model includes this cost driver in the equation or if it is inherent in the basis for the equation, then a densely filled (filled with \\\) box is shown.

CBS Elements	CBS DEPTH SCORE 1 – 5	Cost Driver Categories: HTR Substances: Hazardous / Toxic	HTR Substances: Contact, Remote Radiological	Waste Sources: Mfg, Bases, & Depot Facilities	Waste Sources: Environmental Restoration Sites	Productivity: Personnel Protection Level	Cost Risk: Medic, Liabl, & Regulatory Risk	Cost Risk: Technology, & Scope Risk	Cost Risk: Cost Ranges, & Unknown Risk
1 Environmental Program Management									
.01 Program Management	4	\\\\\\\\	☐	\\\\\\\\	☐		////////		☐
.02 Program Support	3	\\\\\\\\	☐	\\\\\\\\	☐		\\\\\\\\		☐
2 HTR Material Management									
.01 HTR Material Management and Support									
.01 Pollution Prevention Program Implementation	0	☐	☐	☐		☐	☐	☐	☐
.02 Compliance Program Implementation	4	\\\\\\\\	☐	\\\\\\\\					☐
.02 HTR Material Control and Distribution									
.01 Requisition/Acquisition	4	\\\\\\\\	☐	\\\\\\\\					☐
.02 Handling/Distribution	5	\\\\\\\\	☐	\\\\\\\\		////////	////////		☐
.03 Management/Control of Use	4	\\\\\\\\	☐	\\\\\\\\					☐
.04 Recovery	5	\\\\\\\\	☐	\\\\\\\\		////////	////////		☐
.05 Reuse	0	☐	☐	☐		☐	☐		☐
.06 Recycle	5	\\\\\\\\	☐	\\\\\\\\		////////	////////		☐
.03 HTR Material Management Facilities									
.01 Personnel Protection	5	\\\\\\\\	☐	\\\\\\\\					☐
.02 HTR Capital Facilities/Equipment	5	\\\\\\\\	☐	\\\\\\\\				☐	☐

CBS Depth Score

0 ==> Cost tool does not address this CBS element.
1 ==> Cost tool addresses less than 10% of subordinate CBS elements.
2 ==> Cost tool addresses from 10% to 24% of subordinate CBS elements.
3 ==> Cost tool addresses from 25% to 49% of subordinate CBS elements.
4 ==> Cost tool addresses from 50% to 74% of subordinate CBS elements.
5 ==> Cost tool addresses more than 75% of subordinate CBS elements.

CDC Application

==> No box indicates the CDC cell is not applicable.
☐ ==> Cost tool does not address this CDC cell.
//////// ==> Cost tool indirectly addresses this CDC cell.
\\\\\\\\ ==> Cost tool directly addresses this CDC cell.

FIGURE 4-2.—Example of the Summary Level Evaluation Matrix of the HAZMAT Model Evaluation

In our example of the HAZMAT coverage of CBS 2.01, figure 4-1 shows that CBS 2.01.01 is not covered and that CBS 2.01.02 received a score of 4. It also shows that:

- Hazardous/toxic substances are directly considered
- Radiological substances are not considered
- Waste sources for manufacturing, depot, and bases are directly considered
- Cost ranges or cost risks for unknown factors are not considered.

This chapter provides the reader with reference material to interpret the tool evaluation figures presented in chapters 7 and appendix A. The definitions of the CBS activities and CDC factors are provided in appendix B.

5 AGGREGATE COST TOOL EVALUATION

5.1 INTRODUCTION

This chapter presents the environmental cost-estimating capabilities of the composite set of tools. Specific cost tool capabilities are provided in Chapter 7 EM Cost Tool Evaluation.

The Summary Evaluation Matrix presented in figures 5-1, 5-2, and 5-3, shows the cumulative coverage of the evaluated cost models and databases as they apply to the CBS/CDC. The matrix does not show the application of the engineering case studies and reports evaluated in chapter 8. The reports that have application for specific areas are discussed in Section 5.2 Aggregate Cost Tool Coverage.

Figure 5-1 shows that there is modest coverage of the CBS 1.0 Environmental Program Management and significant coverage of CBS 2.0 HTR Material Management. While there is coverage, the cost tools that address these CBS elements have limited estimating capability. Figure 5-2 shows that most of CBS 3.0 HTR Waste Management is not covered at all. Figure 5-3 shows that there is significant coverage of both CBS 4.0 Environmental Restoration and CBS 5.0 HTR Material and Waste Transportation. The cost tools we evaluated that address these latter two CBS elements are by far the most sophisticated providing the cost estimator/analyst with reasonably accurate and analytically flexible models and databases.

The lack of an established database or estimating models that address the first three CBS elements presents a critical gap in the current cost model estimating capability. As shown in the process flow charts in figures 3-1 and 3-2, EM activities are performed iteratively throughout the life cycle of a facility and an MDAP. The greatest potential for cost savings (or cost avoidance) occurs at the front end of the process flow. That is, the greater the extent to which HTR material management is implemented, the greater the reduction in HTR waste streams resulting in substantial cost savings. Likewise, the greater the extent to which HTR waste management is implemented, the greater the reduction in ER liability.

In addition to the gap of CBS coverage left by the tools evaluated, there are some gaps in coverage of the CDC elements. The evaluated cost models and databases address the CDC element for hazardous/toxic substances but not radiological. This does not present a problem for most DoD estimating requirements because most MDAPs are not directly concerned with handling radiological substances other than the well-contained substances in nuclear weapons or the low-level radiological substances in medical products. The decommissioning of nuclear reactors for submarines and surface ships is a notable exception, which may warrant further research to fill this gap.

As shown in these figures, there is a gap in Cost Risk estimating capability. None of the cost tools evaluated provides cost ranges or a contingency estimating routine. The HAZMAT model estimates the cost associated with medical and liability risk elements, but the other

CBS Elements	CBS DEPTH SCORE 1 – 5	Cost Driver Categories: HTR Substances – Hazardous / Toxic	HTR Substances – Contact, Remote Radiological	Waste Sources – Mfg, Bases, & Depot Facilities	Waste Sources – Environmental Restoration Sites	Productivity – Personnel Protection Level	Cost Risk – Medic, Liabl, & Regulatory Risk	Cost Risk – Technology, & Scope Risk	Cost Risk – Cost Ranges, & Unknown Risk
1 Environmental Program Management									
.01 Program Management	4	\\\\\\\\	☐	\\\\\\\\	☐		////////		☐
.02 Program Support	3	\\\\\\\\	☐	\\\\\\\\	☐		\\\\\\\\		☐
2 HTR Material Management									
.01 HTR Material Management and Support									
.01 Pollution Prevention Program Implementation	0	☐	☐	☐		☐	☐	☐	☐
.02 Compliance Program Implementation	4	\\\\\\\\	☐	\\\\\\\\					☐
.02 HTR Material Control and Distribution									
.01 Requisition/Acquisition	4	\\\\\\\\	☐	\\\\\\\\					☐
.02 Handling/Distribution	5	\\\\\\\\	☐	\\\\\\\\		////////	////////		☐
.03 Management/Control of Use	4	\\\\\\\\	☐	\\\\\\\\					☐
.04 Recovery	5	\\\\\\\\	☐	\\\\\\\\		////////	////////		☐
.05 Reuse	0	☐	☐	☐		☐	☐		☐
.06 Recycle	5	\\\\\\\\	☐	\\\\\\\\		////////	////////		☐
.03 HTR Material Management Facilities									
.01 Personnel Protection	5	\\\\\\\\	☐	\\\\\\\\					☐
.02 HTR Capital Facilities/Equipment	5	\\\\\\\\	☐	\\\\\\\\				☐	☐

CBS Depth Score

- 0 ==> Cost tool does not address this CBS element.
- 1 ==> Cost tool addresses less than 10% of subordinate CBS elements.
- 2 ==> Cost tool addresses from 10% to 24% of subordinate CBS elements.
- 3 ==> Cost tool addresses from 25% to 49% of subordinate CBS elements.
- 4 ==> Cost tool addresses from 50% to 74% of subordinate CBS elements.
- 5 ==> Cost tool addresses more than 75% of subordinate CBS elements.

CDC Application

- ==> No box indicates the CDC cell is not applicable.
- ☐ ==> Cost tool does not address this CDC cell.
- //////// ==> Cost tool provides modest coverage of this CDC cell.
- \\\\\\\\ ==> Cost tool provides significant coverage of this CDC cell.

FIGURE 5-1.—Summary Evaluation Matrix: Cost Tool Coverage of CBS Elements 1 and 2 and CDC

CBS Elements	CBS DEPTH SCORE 1 – 5	HTR Substances: Hazardous / Toxic	HTR Substances: Contact, Remote Radiological	Waste Sources: Mfg, Bases, & Depot Facilities	Waste Sources: Environmental Restoration Sites	Productivity: Personnel Protection Level	Cost Risk: Medic, Liabl, & Regulatory Risk	Cost Risk: Technology, & Scope Risk	Cost Risk: Cost Ranges, & Unknown Risk
3 HTR Waste Management									
.01 HTR Waste Operations Management and Support									
.01 Pollution Prevention Program Implementation	0	□	□	□		□	□	□	□
.02 Compliance Program Implementation	0	□	□	□		□	□		□
.02 On–site Waste Management Facility Construction/Ops									
.01 Treatment Facility Design & Construction	0	□	□	□				□	□
.02 Treatment Facility Operations & Equip. Maint.	0	□	□	□		□	□		□
.03 Storage Facility Design & Construction	0	□	□	□				□	□
.04 Storage Facility Operations & Equip. Maint.	0	□	□	□		□	□		□
.05 Disposal Facility Design & Construction	0	□	□	□				□	□
.06 Disposal Operations & Equip. Maint.	0	□	□	□		□	□		□
.03 Closure and Post–Closure Care									
.01 Treatment Facility Closure	4	\\\\	////	□		\\\\	□		□
.02 Storage Facility Closure	4	\\\\	////	□		\\\\	□		□
.03 Disposal Facility Closure	5	\\\\	////	□		\\\\	□		□
.04 Restoration	5								□
.05 Certification of Closure	0						□		□
.06 Post–Closure Care	5								□
.04 Off–site HTR Waste Disposal									
.01 Commercial (Fee)	5	\\\\	////			\\\\	\\\\		□
.02 Other than Commercial (Fee)	5	\\\\	////			\\\\	□		□

CBS Depth Score

0 = = > Cost tool does not address this CBS element.
1 = = > Cost tool addresses less than 10% of subordinate CBS elements.
2 = = > Cost tool addresses from 10% to 24% of subordinate CBS elements.
3 = = > Cost tool addresses from 25% to 49% of subordinate CBS elements.
4 = = > Cost tool addresses from 50% to 74% of subordinate CBS elements.
5 = = > Cost tool addresses more than 75% of subordinate CBS elements.

CDC Application

= = > No box indicates the CDC cell is not applicable.
□ = = > Cost tool does not address this CDC cell.
//// = = > Cost tool provides modest coverage of this CDC cell.
\\\\ = = > Cost tool provides significant coverage of this CDC cell.

FIGURE 5-2.—Summary Evaluation Matrix: Cost Tool Coverage of CBS Element 3 and CDC

CBS Elements	CBS DEPTH SCORE 1 – 5	Cost Driver Categories: HTR Substances: Hazardous / Toxic	HTR Substances: Contact, Remote Radiological	Waste Sources: Mfg, Bases, & Depot Facilities	Waste Sources: Environmental Restoration Sites	Productivity: Personnel Protection Level	Cost Risk: Medic, Liabl, & Regulatory Risk	Cost Risk: Technology, & Scope Risk	Cost Risk: Cost Ranges, & Unknown Risk
4 Environmental Restoration/Corrective Measures									
.01 PA/SI and/or RFA	2	\\\\\\\\	////////		\\\\\\\\				[ ]
.02 RI/FS and/or RFI/CMS	5	\\\\\\\\	////////		\\\\\\\\	\\\\\\\\	[ ]	[ ]	[ ]
.03 Remedial Design	2	\\\\\\\\	////////		\\\\\\\\	\\\\\\\\	[ ]	[ ]	[ ]
.04 Remedial Action and/or Corrective Measures									
Preparatory	4	\\\\\\\\	////////		\\\\\\\\	\\\\\\\\	[ ]		[ ]
On–site Containment / Collection	4	\\\\\\\\	////////		\\\\\\\\	\\\\\\\\	[ ]	[ ]	[ ]
Treatment	5	\\\\\\\\	////////		\\\\\\\\	\\\\\\\\	[ ]	[ ]	[ ]
Decontamination & Decommissioning	4	\\\\\\\\	////////		\\\\\\\\	\\\\\\\\	[ ]	[ ]	[ ]
Off–site Treatment/Disposal	5	\\\\\\\\	////////			\\\\\\\\	[ ]		[ ]
Physical Completion / Closure	3						[ ]		[ ]
5 HTR Material and Waste Transportation									
.01 Transportation Management	0	[ ]	[ ]	[ ]	[ ]				[ ]
.02 Transportation	4	\\\\\\\\	////////	\\\\\\\\	\\\\\\\\	\\\\\\\\	////////		[ ]

CBS Depth Score

0	= = > Cost tool does not address this CBS element.
1	= = > Cost tool addresses less than 10% of subordinate CBS elements.
2	= = > Cost tool addresses from 10% to 24% of subordinate CBS elements.
3	= = > Cost tool addresses from 25% to 49% of subordinate CBS elements.
4	= = > Cost tool addresses from 50% to 74% of subordinate CBS elements.
5	= = > Cost tool addresses more than 75% of subordinate CBS elements.

CDC Application

	= = > No box indicates the CDC cell is not applicable.
[ ]	= = > Cost tool does not address this CDC cell.
////////	= = > Cost tool provides modest coverage of this CDC cell.
\\\\\\\\	= = > Cost tool provides significant coverage of this CDC cell.

FIGURE 5-3.—Summary Evaluation Matrix: Cost Tool Coverage of CBS Element 4 and CDC

Cost Risk elements are not addressed. As evidenced by significant EM cost growth, this lack of cost risk estimating capability is critical. For example, the cost of commercial disposal of hazardous waste has increased exponentially over the past few years. It would be prudent for the cost estimator to assign a cost-risk factor to address this topic. A well-maintained EM cost model/database should provide the estimator with the capability to assess these cost risks and establish an appropriate cost-risk factor.

5.2 AGGREGATE COST TOOL COVERAGE

This section presents an assessment of the coverage of each major CBS element by the evaluated cost tools. Applicable engineering case studies and reports that provide additional estimating capability are discussed. There also are several technical reports, reviewed in chapter 8, that have application to the CBS but which are too narrowly focused for inclusion here.

CBS 1.0 Environmental Program Management

Most of the activities included in this category are generally accounted for as indirect costs or part of the facility overhead. Typically, the cost estimator/analyst simply applies an overhead factor to the MDAP's direct-cost subtotal to account for these activities. Each of the CBS elements should be given consideration by the estimator to determine if the overhead factors are adequate and appropriate. For instance, an overhead cost factor for CBS 1.01.04 Conservation Management may be negligible, but if the MDAP calls for the construction of a facility in a known wetland, a nominal factor will fall far short of capturing the true costs.

Most of the Program Management and Program Support elements comprise the professional labor required to conduct business. For example, a manufacturing business must have the support of legal counsel to determine the legal and regulatory requirements to deal with EM issues and to deal with legal claims.

These Program Management and Program Support elements are relatively insensitive to specific manufacturing/maintenance processes. That is, a change in a manufacturing process is not likely to affect directly the size or cost of the program management staff. Because the Cost Estimating Relationships (CERs) between the EM Program Management CBS elements and the manufacturing and maintenance processes is indirect, it is difficult to model. The CERs for these activities are a function of the facility business base, regulatory interaction, and other non-parametric factors. Environmental Program Management should be estimated at the facility level where the total cost for these elements can be assessed and allocated to the facility projects/programs responsible for them. The most likely estimating methodology to employ is an analogy based on historical cost (if historical cost data are available) or an estimate of the total number of management and management support personnel required for each facility.

The HAZMAT model addresses the elements as indicated in Figure 5-1. This model can be used provided the estimator has the requisite input information. For example, training cost inputs include: number of personnel requiring training, the duration of their training, their wage rates, and the training course cost. A full HAZMAT evaluation is provided in

chapter 7. No other cost model, database, or engineering case studies or report addresses this CBS element.

CBS 2.0 HTR Material Management

HTR Material Management activities are those that directly support on-going manufacturing and maintenance processes. These activities are highly integrated with these processes and in some cases may not be identifiable as discrete activities. For example, a chemically etched part is likely to be estimated with a CER based on cost per pound. The CER may include the cost of acquiring, handling, and managing hazardous material as well as the process operation cost itself. Therefore, the cost estimator/analyst must be cognizant of the environmental cost elements and assure their inclusion in the MDAP LCC, but to identify them separately may be infeasible.

As shown in figure 5-1, HAZMAT addresses this important part of the EM life cycle. Its internal database and the associated weapon system reports (for the F-15, F-16, B-1, and C-130 aircraft, Titan IV space launch vehicle, Black Hawk helicopter, M1-A1 tank, and Mark 50 torpedo) provide a valuable source of information regarding environmental costs at the manufacturing, operational base, and depot facilities. However, HAZMAT will not provide the user with the total weapon-system environmental LCC for the CBS elements it addresses.

HAZMAT may be useful in conducting trade-off studies, but the cost estimator/analyst conducting the study must exercise caution. Unless factors such as Facility Cost Per Pound of Substance Used can be entered with certainty, HAZMAT can only provide relative cost estimates for comparable alternatives. Also, because some of the process-level factors are insensitive to the type of hazardous material, a trade-off study between alternative substances will not provide a complete assessment of cost. It is our understanding that the next version of HAZMAT will provide this sensitivity.

Because the HAZMAT model requires substance- and process-level data, a detailed weapon system manufacturing/maintenance plan (or at least a conceptual design of the process) will be required. In short, HAZMAT does not lend itself to parametric estimating in the early life-cycle phases of weapon system design.

One other cost model addresses this subject area: the Navy's Hazardous Materials Life-Cycle Cost Model (HMLCCM). This model includes virtually the same CBS elements as the HAZMAT model. The current version of HMLCCM and its associated documentation are insufficient to assess its application. For example, the model calls for inputs on the number of employees and the number of days. It is not clear how the model uses these inputs. The number of days is limited to less than 1,000, and it is, therefore, apparent, that the model is not estimating an annual cost. The output is an estimated cost for each chemical included in the run. The reported cost figure is not defined in terms of units (single, hundreds, thousands, or millions of dollars), year of economics, direct or burden, or time frame represented. Therefore, the Project Team did not conduct a full evaluation of HMLCCM.

CBS 3.0 HTR Waste Management
Activities under this CBS element include recovery of HTR substances; performance of all treatment, storage, and disposal requirements; and final disposition of the facilities. Unlike HTR Material Management activities, these activities are discrete. Each of the CBS elements can be identified and estimated using conventional estimating techniques. Costs for facility construction and equipment installation can be estimated using well-developed construction estimating cost models and databases. The treatment, storage, disposal, facility operations, maintenance, and decommissioning will require a unique model for each facility type. The facility closure activities can be estimated using ER models. It should be mentioned that although these activities are discrete, they may still be difficult to identify with a given MDAP because they are facility-related.

Feizollahi and Shropshire[3] present cost curves that can be used to generate first-order (or rule-of-thumb) cost estimates for hazardous waste facility construction, operation, and decommissioning. These cost curves are a black box, however, without the back-up cost information presented in another document.

None of the evaluated cost models addresses HTR Waste Management Facility Construction (CBS 3.2) or Operation (CBS 3.3). Potentially, RACER-ENVEST and MCACES can estimate specific waste-management technologies such as incineration. This potential must be further investigated because the technologies included in RACER-ENVEST and MCACES have a significantly different design than those included in waste-management facilities.

RACER-ENVEST can be used to parametrically estimate the facility Closure and Post-Closure Care element (CBS element 3.03). This CBS element usually is not applicable to the MDAP LCC because most facility closure costs are not allocated to any weapon system. It is most likely applicable in the case where the facility to be closed is dedicated to one weapon system.

Both RACER-ENVEST and HAZMAT can be used to estimate the Off-Site Treatment and Disposal elements (4.04 and 4.19).

In addition to the *Interim Report*, there are four engineering case studies and reports reviewed in chapter 8 that are applicable to HTR Waste Management. They are:

Roberts, R. M., J.L. Koff, and L.A. Karr. *Hazardous Waste Minimization Initiation Decision Report,* Naval Civil Engineering Research Laboratory, TN-1787, June 1988, Volume 1 (AD-A199221), Volume 2 (AD-A199222).
This report provides an extensive amount of technical information regarding the Navy's waste management activities. The cost information is at a very high level, however.

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[3] F. Feizollahi and D. Shropshire. *Interim Report: Waste Management Facilities Cost Information for Hazardous Waste*, EG&G Idaho, Inc. for the U.S. Department of Energy Idaho National Engineering Laboratory, EGG-WM-11432, August 1994.

The cost estimator/analyst may be able to use the cost data as analogies to develop rough order of magnitude estimates.

Sinski, Patricia M., Robert Martin, and J.R. Finney. *Evaluating Cost Estimates for Closure and Post-Closure Care of RCRA Hazardous Waste Management Units,* developed for the U.S. Environmental Protection Agency Region IV, Atlanta, Georgia, by PRC Environmental Management, Inc., Work Assignment No. R04049, May 13, 1994. [No secondary source identified.]

This report provides cost equations in the form of cost tables to calculate the RCRA Closure and Post Closure Care cost. It is our understanding that a companion cost model is in development.

Kim, B.J., et al. *An Analysis of Army Hazardous Waste Disposal Cost Data,* developed for the U.S. Army Corps of Engineers, Construction Research Laboratory, USA CERL-TR-N-91/17, April 1991, AD-A236654.

This report includes a sizable database of disposal-cost information acquired from several Army installations. This may be a useful reference document to the cost estimator/analyst.

Kuryk, B.A. *Economic Analysis of the Recovery and Reuse of Explosives from Obsolete and Unserviceable Conventional Ammunition,* developed for the U.S. Army Toxic and Hazardous Materials Agency by Arthur D. Little, Inc. ADI/REF-54144-03, May 31, 1986, AD-A170445.

While this document is specific to explosive disposal, it may have broad application to MDAPs.

CBS 4.0 Environment Restoration/Corrective Measures

This element of the CBS is most thoroughly covered by existing cost models and databases (HCAS, RACER, and MCACES). It is the least applicable to the MDAP LCC, however. If the environmental program management activities are successfully accomplished, then no ER (or corrective measures) will be required. The most direct application of these tools, therefore, is in estimating the costs of weapon-system-related facility closure and post-closure care.

Evaluations of ER models and databases are presented in chapter 7. In addition, several engineering case studies and reports address this CBS element. Because they are not of direct concern to the typical MDAP LCC estimate, they are not discussed here. See chapter 8 for information regarding them.

CBS 5.0 HTR Material and Waste Transportation

This element of the CBS does not present a difficult estimating problem. Transportation costs are relatively small and, in some cases, are included in HTR material acquisition or HTR substance disposal cost-per-pound factors.

Both RACER and HAZMAT address this cost element. These cost models assume that transportation will be by truck and within the continental US. These models do not address

the transportation of explosives or radiological substances. *Economic Analysis of the Recovery and Reuse of Explosives* includes transportation cost, however.

5.3 PERSPECTIVES ON ENVIRONMENTAL COST ESTIMATING

Because devoting excessive attention to estimating one area of LCC poses a serious risk of misestimating in other areas, a dictum cost estimators/analysts should follow is:

> The effort applied to estimating environmental costs should be proportionate. That is, if the environmental portion of a program is expected to amount to X% of the total program LCC, the cost analysis staff should expend about X% of its effort estimating it.

One of the problems facing a cost estimator/analyst is identifying and estimating EM costs. The challenge with such embedded costs is ensuring that they are fully represented in their parent cost accounts. As discussed above, CBS 1.0 Environmental Program Management and CBS 2.0 HTR Material Management activities may be difficult or impossible to separate from other MDAP manufacturing and maintenance activities.

Environmental cost estimating and reporting was addressed at the workshop that developed the ECES (see section 3.2). The following passage is excerpted from the final report for the "Workshop on the Environmental Life Cycle Cost Estimating for Weapons Systems" (June 1994).

> Requirements to identify costs reported separately from those of weapons systems as "environmental costs" are to be addressed as follows:
>
> - The weapon system cost analysis requirement document . . . must have all environmental . . . requirements and environmental goals/directives stated explicitly. The goal of the component cost element structure and its integration in the CCA process is to examine environmental quality issues.
>
> - All environmentally-related [sic] costs are therefore fully integrated into the life-cycle cost of a weapons system, just as are other categories of costs (e.g., weight limitations, radar avoidance requirements, target detection and combat maneuverability). Therefore, although environmental issues may stimulate process changes or system improvements in weapons systems, the costs for these changes and improvements inherent in the acquisition process are difficult and, in some cases, impractical to separate from other costs.
>
> - If required to identify "environmental costs" associated with the introduction of a weapons system, the consensus on which costs are to be specified as "environmental costs" are those costs directly associated with compliance-driven activities (e.g., process, equipment, fees, labor, materials). These costs are those that can be directly allocated to meeting specific regulations and directives imposing the limitation on environmental impacts.

Although the CBS cost elements should be considered when developing an LCC estimate, they can be included in the estimate either explicitly or implicitly. The important point is that the EM costs are included—and included only once—in the LCC estimates.

6 SHORT-TERM/LONG-TERM PLAN

Existing tools leave critical cost-estimating gaps in CBS 2.0 HTR Material Management and CBS 3.0 HTR Waste Management. Section 6.1.1 proposes a quick fix to the HAZMAT model to fill these gaps associated with CBS 2.0 in at least a cursory fashion. Section 6.1.2 addresses the use of engineering case studies to develop cost-estimating capability for CBS 3.0. The Short-Term Plan also proposes using the CBS/CDC to develop a comprehensive environmental estimate (or comprehensive trade-off study) for an MDAP actually in development. Finally, the Short-Term Plan proposes a data-collection strategy to be followed during implementation of the Long-Term Plan. The primary elements of the Long-Term Plan are proposals to develop a comprehensive EM cost-estimating and -evaluation system to include all CBS elements and cost-tool testing, verification/validation, and maintenance procedures.

6.1 SHORT-TERM PLAN

The three primary elements of the Short-Term Plan are discussed in the following sections.

6.1.1 Quick-Fix to the HAZMAT Model

The Project Team's evaluation of the cost tools shows that HAZMAT is the only model, with sufficient documentation for evaluation, that addresses CBS 2.0. Because the basis for HAZMAT is well documented, it provides a good foundation for further development. Specific recommendations to enhance the current version of HAZMAT are presented in section 7.2.7.2. In general, the quick-fix recommendations to HAZMAT are to:

- Define and document the internal database for manufacturing/maintenance processes, hazardous substance properties, and cost-factor development
- Provide the capability to estimate the total MDAP LCC for EM (for the CBS elements HAZMAT currently addresses)
- Provide analytical flexibility to develop weapon-system (or -subsystem) -level analogies and generate a wider variety of reports
- Investigate the Navy's HMLCCM model to determine its cost basis and potential value to supplement HAZMAT.

6.1.2 Develop Initial HTR Waste Management Estimating Capability

SCM, originally selected for evaluation, addresses CBS HTR Waste Management. However, the Project Team determined, after an initial evaluation of this model, that it does not have application to DoD. The current version was developed to conduct DOE-wide waste management trade-off studies, requires the selection of one or more DOE sites, and more importantly, does not address hazardous substances. The tool deals with the facility and operational requirements for radioactive waste; the costs of hazardous-waste management are

minor in comparison to the costs of radioactive-waste management and so are not included in the model.

However, the developers of SCM also prepared the *Interim Report: Waste Management Facilities Cost Information for Hazardous Waste* using a sound, detailed, bottoms-up estimating approach. A conceptual design for each of the cost modules (e.g., aqueous waste treatment, incineration) was developed based on analogous systems. The back-up cost information provides a facility-design schematic, an equipment list, an operational process flow diagram, and pertinent estimating assumptions and bases. Manpower requirements, labor rates, equipment cost data, and other cost factors (e.g., material costs, utility expenses, facility maintenance) were documented for small, medium, and large facilities by WBS element. Then regression analyses were performed to establish CERs based on the high-level parameters such as facility capacity. Cost curves for each of the cost modules are presented.

The *Interim Report: Waste Management Facilities Cost Information for Hazardous Waste* provides only a summary of the design and cost data described above. The back-up cost information has not yet been released, and the Project Team had only this summary document for evaluation. Whether the back-up cost information will be available to the DoD cost community has not been determined. Should that information become available, we recommend that it be examined to determine whether the information can be used as the foundation for HTR Waste Management cost-model development.

Other engineering case studies and reports may be useful in developing EM cost-estimating capabilities in the short term.

- *Hazardous Waste Minimization Initiation Decision Report* (Roberts, Koff, and Karr)

  This two-volume report provides a wealth of information on the U.S. Navy's generation, management, and remediation of hazardous waste and their associated costs.

  Volume I contains a summary of the processes that generate hazardous waste, the volume of such waste, and the current and emerging technologies that can be applied toward its management and treatment.

  This report may provide a good starting point for a cost and technical data-collection effort to support the Long-Term Plan data-collection strategy discussed in section 6.2. The report should be further investigated during the short-term to assess the applicability of the reported top 19 industrial processes and associated hazardous waste streams to the DoD at large. Only total cost information is provided for the treatment of a number of hazardous wastes generated by these processes. If back-up cost information exists, it should be collected, analyzed, and categorized according to the CBS/CDC.

  This report should be used to supplement the technical-cost data gathered from the *Interim Report: Waste Management Facilities Cost Information for Hazardous Waste* or

(in the event that the back-up cost information for that report is not available) to provide the foundation for HTR Waste Management cost-model development.

- *Evaluating Cost Estimates for Closure and Post-Closure Care of RCRA Hazardous Waste Management Units* (Sinki, Martin, and Finney)

  This manual offers a method by which EPA and State RCRA permit writers may evaluate the accuracy of cost estimates for closure and post-closure care of RCRA treatment, storage, and disposal units prepared by the owners of those units. The method focuses on cost estimating for specific closure activities associated with common types of treatment, storage, and disposal units.

  We suggest that the technical design used to generate the cost tables in this document be acquired. These designs should be evaluated with respect to the designs generated by the RACER model. Differences should be reconciled and RACER should be updated to model RCRA closure activities.

- *An Analysis of Army Hazardous Waste Disposal Cost Data* (Kim et al.)

  This report provides information on unit costs and total costs incurred in the disposal of many types of Army hazardous waste. The cost data were obtained from the Defense Reutilization and Marketing Service (DRMS), which in turn derived the information from hazardous waste disposal contracts. The data include costs incurred in the disposal of all Army-generated hazardous waste in the Continental United States during fiscal year (FY) 1988.

  The information provided by DRMS is given by Contractor Line Item Numbers (CLINs) that specify several thousand types of hazardous waste materials ranging from solvents to batteries, sludges, oils, and paint-stripping waste. Each CLIN is classified according to type of waste, amount of waste, and container. Descriptive titles for most CLINS are given in the report.

  The report provides maximum, minimum, and average unit costs for each CLIN and the total FY 1988 disposal cost for the top 20 CLINs. It also contains contract dollar values for all waste disposal contracts active during FY 1988.

  We suggest that this report be updated and used to establish a comprehensive hazardous waste-disposal cost database. This should be a fairly simple task to accomplish if the information is readily available in an electronic format. Further, we suggest that the information be incorporated into the EM cost-estimating system discussed in section 6.2.

- *Economic Analysis of the Recovery and Reuse of Explosives* (Kuryk)

  This report is a study of the costs associated with the disposal or recovery of obsolete and unserviceable conventional ammunition.

We suggest that this report be updated and used to supplement the hazardous-waste disposal database with information on explosives.

6.1.3 Develop a Comprehensive Environmental Estimate for a Selected MDAP

A comprehensive estimate of environmental costs of an MDAP should be developed to:

- Verify the existing cost-model operation
- Verify that CBS and CDC elements are appropriate
- Establish additional cost-data collection requirements.

The selected MDAP will be a system in development and approaching a DAB review so that real-time estimating conditions can be assessed and shortcomings of the current EM cost tools can be identified. The following steps are recommended:

- Establish an environmental-cost-estimating integrated product team (IPT) comprising environmental engineers, cost professionals, and program office staff to
  - Review, and modify as necessary, the CBS and CDC to capture historical environmental-cost data.
  - Develop generic manufacturing and maintenance process operation categories. These categories will be central to developing a comprehensive EM cost-estimating and -evaluation system. Each category will include those processes that have similar characteristics including
    - Type of operation (e.g., machining, chemical processes) and associated facility requirements
    - Type of hazardous substances (e.g., flammable, corrosive), toxicity, and form (solid, liquid, or gas)
    - Level of personnel protection required.
- Prepare a trade-off study protocol to
  - Use existing models and reports to the extent possible to generate the estimates
  - Report the methodology employed and recommend a methodology that could be used by cost analysts to conduct similar trade-off studies.

Under the direction of the IPT, a cost-estimating team will conduct the EM cost estimate/trade-off study. Conducting the estimate will require collecting cost data from selected manufacturing and maintenance facilities. The cost estimating team will:

- Develop an objective, comprehensive, and realistic EM cost estimate/trade-off study between technical alternatives that use or generate hazardous substances during weapon-system manufacturing or maintenance processes

- Identify specific trade-off studies to verify cost-estimating capabilities for CBS elements 1.0, 2.0, and 3.0

- Identify weak areas of the estimates and/or any questionable assumptions that were made to complete the trade-off study

- Recommend any further modifications or tool development required to round out the cost estimator's tool kit.

6.1.4 Develop the Long-Term Plan Data-Collection Strategy

Section 6.1.3, discussed an EM cost-database structure and the collection of cost data for cost estimates/trade-off studies. This section (6.1.4) discusses a modification of this database structure based on an analysis of the results of the cost estimates/trade-off studies.

The ultimate EM cost data collection and cost-reporting requirements for DoD should be determined by the IPT. The IPT should develop a comprehensive and cost-effective data-collection strategy. This strategy should be based on modifications to the database structure made as a result of the cost estimates/trade-off studies. We suggest that the IPT develop a detailed data-collection strategy to implement in the Long-Term Plan. This strategy should include:

- Supplementing the latest version of the Long-Term Plan to incorporate new findings from the MDAP cost estimate/trade-off study

- Identifying sources of data required to implement the Long-Term Plan in terms of both the process categories and the CBS/CDC

The data-collection strategy should be based on the priority of the missing (or insufficiently covered) environmental cost elements. This priority will be determined by the relative importance of the element (magnitude of cost) and the frequency of occurrence within MDAPs.

6.2 LONG-TERM PLAN

The Long-Term Plan provides an orderly approach to replacing the expedient steps of the Short-Term Plan with well-founded models, databases, and analytical methods. The Long-Term Plan provides practical plans of action over a 3- or more-year period to fill the gaps in the cost estimator's tool kit that will remain after implementing the Short-Term Plan. The Long-Term Plan also addresses maintaining and updating the tool kit. The Long-term Plan presented here will be further defined and updated as more data become available during implementation of the Short-Term Plan.

The primary product of the Long-Term Plan is a comprehensive environmental management cost-estimating and -evaluation system that will include all CBS elements. During implementation of the Long-Term Plan, a follow-up to the EM cost estimate/trade-off study should be implemented to prototype this system-development effort.

6.2.1 Develop a Comprehensive Environmental Management Cost-Estimating and -Evaluation System

A comprehensive EM cost-estimating and -evaluation system should be developed that focuses the EM cost-estimating requirements for contractors, program office staff, and others in the DoD cost community. We suggest that the IPT provide guidance to the DoD cost community on environmental cost estimating. The proposed estimating system must be sensitive to the different estimating requirements between MDAPs. The estimating system also must be sensitive to differences in estimating requirements for contractor and program office personnel closest to the weapon-system manufacturing or maintenance (i.e., at a fine level of detail) and to those of higher levels of management (e.g., parametric information).

This system should provide the user with the ability to make weapon system- and subsystem-level estimates. The magnitude of the estimates will reflect the total cost for the estimated cost elements and/or relative costs as required. The system development should be based on a parametric approach similar to that used in the RACER cost model and require only high-level weapon-system design parameters to generate a complete estimate. It also should provide detailed unit-cost database/model capabilities similar to those in MCACES. The proposed system may require more than one software program. It may be most expedient to develop separate modules for a historical database, a bottoms-up estimating system, and a parametric system.

The system also should provide the user with a complete facility perspective for each system or subsystem based on generic EM scenarios for weapon-system manufacturing, base operations, depot maintenance, weapon-system disposal, and RCRA closures.

We recommend that the IPT review the merits of each estimating system to determine the extent to which it should be developed. The IPT should consider the analytical flexibility of each system, particularly its ability to:

- Account for and modify the quantities of hazardous materials (a material flow balance routine) through all manufacturing and maintenance processes, storage, treatment, and final disposition (reuse, recycle, or disposal)
- Review default toxicity and physical properties of the substance and its effect on personal protection, treatment, storage, and final disposition
- Review model defaults for facility conditions (e.g., overhead factors, business base) and modify the defaults accordingly
- Review model defaults for manufacturing or maintenance process flow and modify the defaults accordingly.

The cost-estimating system should consider:

- Types and quantities of hazardous materials
- Hazardous material characteristics (e.g., toxicity, physical properties)
- Manufacturing and maintenance processes
- Resulting waste streams (treatment, storage, reuse, recycle, disposal) paths
- Closed system methodology (a system that accounts for the material balance of all input and output flows) to account for the total hazardous/toxic substance and waste stream quantities generated by manufacturing and maintenance processes
- Facility requirements (design, construction, operation, and maintenance).

We strongly suggest that the system, to provide the information needed to develop CERs and/or verify existing CERs, be based on a well-maintained historical EM cost database. The database structure should be based on the CBS and CDC to provide the required definition of historical cost elements. A Government version of the database should be provided that gives authorized users full access to proprietary data.

6.2.2 Develop EM Cost-Tool Maintenance, Testing, and Verification and Validation Procedures

Procedures to maintain, test, and verify and validate EM cost tools must be established. The plan will include continued development and maintenance of a project cost database representative of the majority of MDAP EM requirements and continued enhancement and maintenance of resulting tools. Two components of the plan are:

- An analytical-tool maintenance plan to keep pace with constantly changing environmental regulatory requirements and new environmental technologies. The analytical-tool maintenance plan will emphasize the quality requirements for the tool set and methodologies.
- A cost-tool validation plan for the cost models and databases will investigate the feasibility of validating actual cost and technical data included in the database and validating the cost-model algorithms.

The IPT will provide guidance and help to develop the Short- and Long-Term Plans balancing the need for a complete environmental-cost-estimating tool set with the immediate need for environmental-cost estimating tools.

7 EVALUATION OF EM COST-ESTIMATING MODELS AND DATABASES

7.1 INTRODUCTION

The Project Team performed an independent evaluation of each cost tool. These tools include EM cost-estimating models, EM cost databases, and engineering case studies and reports. The tools were evaluated to determine their coverage of the CBS and CDC. Specifically, each was analyzed to determine which CBS elements it addressed and at what level. The results of each analysis are presented in a Detailed Evaluation Matrix (appendix A). The range and depth of coverage of the cost tools were calculated from this detailed matrix and are presented in the summary evaluation matrices in this chapter. The range of coverage refers to the number of CBS elements addressed in the summary evaluation matrix. The depth, as indicated by the Depth Score, is the percentage of subordinate CBS elements addressed by the tool for the given CBS element. The CDC coverage also was analyzed and is presented in summary evaluation matrices. The coverage scale indicates the degree to which a tool addresses the cost drivers for each CBS element. See chapter 4 for a complete discussion on the evaluation matrix application.

In addition, the cost tools were evaluated from a user's perspective. The methodology and basis of each cost tools are discussed; basic model operation is described; and key attributes are evaluated to determine the appropriate use of the model. The analytical flexibility of each model was evaluated to determine the extent to which it can be customized to meet site-specific conditions and accommodate site-specific information.

The remainder of this chapter reports on the results of the evaluations of EM cost-estimating models and databases. The evaluation of engineering case studies and reports is presented in chapter 8.

7.2 EM COST MODEL EVALUATIONS: HAZMAT

Full citations for the documents cited in sections 7.2.1–7.2.6 are provided in sections 8.2 and 8.3. and appendix C.

7.2.1 Abstract

The Analytical Sciences Corporation (TASC), under contract to Human Systems Center, Brooks Air Force Base, developed the HAZMAT model and supporting documents. The HAZMAT development effort began in 1990 and is ongoing. The Project Team used the latest version HAZMAT (3.1) and the following supporting documentation to conduct its evaluation.

- *Hazardous Materials Life Cycle Estimator User's Guide Version 3.1* (July 8, 1994)
  The *Guide* provides a good explanation of how to use the model. An appendix describes the estimating algorithms. The weapon system reports and the system reports and the *System Administration Manual* (see next bullet) provide the user with a complete picture of the HAZMAT model and basis.

- *Hazardous Materials Life Cycle Estimator System Administration Manual* (April 29, 1994)
  This manual was developed by TASC to provide the HAZMAT System Administrator with the information necessary to modify certain parameters contained in the HAZMAT model. The Project Team used the Phase/Process Information included in appendix C of the manual in developing the F-16 estimate presented in section 7.2.6.

- *Hazardous Materials Management Life Cycle Cost Model; Model Validation Report* (May 18, 1992)
  The *Model Validation Report* describes the model-validation method employed, the cost-data collection effort, the estimate for the F-15 program (the weapon system for which actual data were used as the standard of comparison for the HAZMAT estimate), and the results of the validation. The Project Team reviewed this report to gain further insight into HAZMAT operation and assumptions.

- *Hazardous Materials Management Life Cycle Cost Model Phase I* (March 31, 1991)
  This report documents the HAZMAT Cost Element Structure, cost-model development methodology, data-collection procedures, and basis of the cost estimates for the F-16 and B-1 weapon-system programs. The Project Team used this document in developing the F-16 estimate (see section 7.2.6). TASC has developed weapon system reports similar to the F-16 and B-1 report for each weapon system evaluated.

HAZMAT was developed to support DoD pollution-prevention initiatives conducted throughout a weapon system's life cycle. HAZMAT was designed to perform cost trade-off studies and analyses between currently used hazardous materials and other, less hazardous or nonhazardous, materials. The objective of these studies and analyses is to provide the data necessary to make informed decisions on reducing the kinds and amounts of hazardous materials used in weapon systems' development, production, maintenance, and decommissioning processes. The *Model Validation Report* states, "The purpose of the model [is] to provide a tool for hazardous material evaluation and to estimate the total cost of employing hazardous materials in Air Force weapon systems." Or, as the *User's Guide* notes, "The system is designed for System Program Office (SPO), contractor, and repair depot personnel to assess the cost of using hazardous materials in current and future weapon systems."

These statements imply that HAZMAT produces estimates for the total environmental cost of a weapon system; such is not the case, however. HAZMAT produces estimates only at the manufacturing and maintenance process level of detail (e.g., painting, inspecting, avionics - repair). HAZMAT was originally intended to produce estimates at the weapon-system level,

but the current version (3.1) cannot produce such estimates if the user stays within the model parameters. The latest version of HAZMAT (3.1) has limitations that earlier versions did not have. These limitations, discussed in table 7-2, were introduced as a result of satisfying a new requirement that the user estimate reside on a floppy diskette. As shown in section 7.2.4, HAZMAT cannot be used to reproduce the costs reported in the weapon system reports. The *Model Validation Report* shows that a cost estimate *can* be developed at the weapon-system level with appropriate manipulation, but our evaluation shows that the user must overcome considerable obstacles to do so. We do not challenge the assertion that the model can be used to provide cost trade-off studies and analyses between currently used hazardous materials and other, less hazardous, materials.

HAZMAT is based on a database of acquisition, operations and maintenance, and decommissioning/disposal processes and associated hazardous substances derived from aircraft, ground vehicles, space launch vehicles, and selected subsystems. Specifically, its database is limited to the systems shown in table 7-1. In addition to estimating costs associated with these processes and substances, the model considers management-related costs. These costs and others are included in an internal cost-element structure. A discussion of these cost elements and their relation to the CBS and CDC is included in section 7.2.4, but in general, HAZMAT addresses the CBS element 2.0 HTR Material Management and the CDC element Medical, Liability, and Regulatory Cost Risk.

		HAZMAT MATERIAL PHASE		
SERVICE	SYSTEM	ACQUISITION	OPERATING & SUPPORT	DISPOSAL
Air Force	F-15	//////////	///////////	//////////
	F-16		///////////	//////////
	B-1		///////////	//////////
	C-130	//////////	///////////	//////////
	Titan IV	\\\\\\	///////////	
Army	Black Hawk		///////////	
	M1-A1	-----------	///////////	
Navy	Mark 50		///////////	

Key:
//// Complete
\\\ First and Second Stage
---- Transmission only
Source: *Hazardous Materials Life Cycle Estimator User's Guide*, Version 3.1 (8 July 1994). Human Systems Center, Brooks AFB, Tx.

TABLE 7-1.—HAZMAT Systems Application

7.2.2 Database/Model Development Methodology

A HAZMAT development team visited selected manufacturing and maintenance facilities to assess hazardous material management practices. Processes that use or produce hazardous substances were identified, and the facility-wide annual cost for each process was estimated. When the total facility cost for a given process was available, that cost often represented the cost of several programs (e.g., other weapon system programs or other facility business). However, the development team calculated the cost to be allocated to the subject weapon system based on the ratio of pounds of the subject weapon system to the total pounds for all weapons (and civilian) systems manufactured or maintained at the facility. Because HAZMAT's environmental cost data are largely based on this allocation, they are sensitive to the facility business base, other facility conditions such as production line capacity and utilization, and the portion of the production line associated with the subject system.

There are limitations to the HAZMAT database. As shown in table 7-1, the database has relatively little acquisition-phase data and, therefore, manufacturing data. Also, the HAZMAT development team visited each facility only once for each weapon system investigated. In many cases, the cost collected for the year visited was assumed to represent the annual cost for the facility. This may be a dangerous assumption depending on the variability of the annual cost during the production or maintenance life cycle. This assumption implies that the facility is operating in a steady-state and that no further pollution-prevention initiatives have been implemented or regulatory requirements levied that would significantly affect the process cost. Moreover, in some cases, historical cost data for a weapon system cost element were not available, so they were estimated based on analogy to another weapon system.

Upon completion of the weapon-system data-collection effort, the HAZMAT development team calculated the total LCC from the annual cost for each of the HAZMAT cost elements (e.g., procurement, transportation) and for each phase (acquisition, operations & support and decommissioning). These calculations are fully documented for each weapon system evaluated in weapon system reports. The development team used the weapon system reports as a basis for developing HAZMAT. The rationale employed to develop the model algorithms from the system report data is not documented. Therefore, how the data were used to generate the equations and algorithms included in the model is not clear. For this report, the Project Team used the F-16 weapon system report included in the *Hazardous Materials Management Life Cycle Cost Model Phase I* report to perform its evaluation of the HAZMAT model.

A formal cost-model validation was performed by TASC to lend credibility to the HAZMAT model. The *Hazardous Materials Management Life Cycle Cost Model; Model Validation Report* (May 18, 1992) states:

> The purpose of this effort is to validate the HMM LCC Model [HAZMAT] in accordance with Air Force Cost Center requirements. The TASC team gathered actual cost data for hazardous materials used on the F-15 weapon system. The model currently contains data for the B-1, F-16, and aircraft engines. Model validation requires that the

model be exercised on a system that is not contained in the database and the model results be compared to actual data on the system selected for validation. Model inputs for the F-15 were derived and the model was exercised using these inputs. The model output was then compared to the actual cost data for the purpose of model validation.

The following is from the *Model Validation Report* regarding the validation process.

> The output of the model is by phase (Development, Production, Operating and Support, and Disposal) and by cost element (Procurement, Medical, Personal Protection, Handling, Management, Legal/Environmental, and Disposal). The results of the model were compared to the actual data collected. If the results of the model are within 15 percent of actual, then the model will be considered validated. [Note: This validation includes 7 of the 12 cost elements considered to represent 95% of the total cost.]
>
> . . . If the output of the model differs by more than 15 percent from actual, then reconciliation of the data and the model algorithms will be necessary. One possible cause of the model results differing from actual is that a process used in the model for a specific maintenance action is not the same process used for that same maintenance action on the F-15. An example of this is the paint stripping process. The model is based on the method of plastic media blasting (PMB), which is used on the F-16. If a different method is used on the F-15, i.e., chemical stripping or the use of carbon dioxide pellets, this could cause differences in the model outputs as compared to actual.

This validation shows that an estimate for the total costs for hazardous material management of a weapon system can be generated using the model. The validation also shows that the user of the model must be aware of the process operations included in the database and how they compare to the process operations for the weapon system being estimated.

The validation results show that although the cost model runs were adjusted to account for differences in these process operations (and associated substances) between the F-16 and F-15 programs, the cost model runs still required reconciliation for the Handling and Medical cost elements. The validation effort was sufficient to verify cost model operations and algorithms but was not sufficient to validate an environmental LCC estimate of a weapon system not in the database without cost adjustments outside of the model.

Our evaluation shows that the user must overcome many obstacles to perform an LCC estimate for a weapon system. In addition to those obstacles (discussed in section 7.2.3) another obstacle was introduced with the later versions of HAZMAT. Version 3.1, for example, has an input limitation on the number of substances that can be selected for each process. Due to this limitation, the Project Team could not duplicate the validation runs. Therefore, to evaluate the HAZMAT model, the Project Team ran an estimate for the entire

F-16 Operations & Support phase to test the results against the F-16 cost reported in the weapon system report. The results of our evaluation are presented in section 7.2.6 below.

7.2.3 Database/Model Organization/Operation

HAZMAT is designed for use on an IBM-compatible microcomputer using the MS-DOS operating system with a minimum of 640Kb random access memory (RAM), 20 megabytes on the hard drive, and an EGA or VGA monitor. HAZMAT has well-defined input screens that lead the user through logical steps to develop the estimate. The help screens are easy to use and define all the components of any given screen.

The *User's Guide* provides a good explanation of how to use the model. An appendix to the *User's Guide* describes the estimating algorithms. The weapon system reports and the system administration manual provide the user with a complete picture of the HAZMAT model.

As discussed in section 7.2.2, the HAZMAT cost model is based on the cost data included in the weapon system reports. The cost for each element (e.g., procurement, handling) is defined by the model in terms of cost factors (e.g., handling cost per pound of substance used). The HAZMAT compiles these cost factors for all substances and processes for each of the weapon systems addressed. That is, this is a database of factors not of cost elements. The database includes several default cost-per-pound factors for each substance and process in the database; it does not include the original cost elements as presented in the weapon system reports. The HAZMAT model is a database program containing these cost factors and software routines to execute algorithms to calculate the process cost for each of the 12 cost elements. The following definitions of the cost elements estimated by HAZMAT are from appendix B of the *User's Guide*.

- *Procurement* includes the actual purchase price of the hazardous materials plus the cost of transportation to the manufacturing, depot, or operating site (of use).

- *Transportation* captures the cost of transporting hazardous materials from one location to another at the site of use.

- *Personal Protection* consists of three sub-elements

  - Cost of the personal protection equipment including maintenance and support
  - Cost of inefficiency as a result of wearing the equipment
  - Cost of dispensing the equipment.

- *Management* includes those functions necessary to maintain oversight of the hazardous materials at the locations where they are used (primarily a labor cost).

- *Training* accounts for the cost of training personnel in the proper

  - Handling, storage, and use of hazardous materials
  - Use of personal protection equipment.

- *Handling* is the cost of

  - Subdividing, labeling, and distributing the materials
  - Lost productivity due to the controls placed on the hazardous materials and their distribution.

- *Potential Legal/Environmental Liability* covers potential liability for violations of 12 Federal environmental acts of liability laws including special provision for violations of the Clean Air Act. (Potential Legal/Environmental Liability is directly related to the amount of hazardous waste disposed.)

- *Medical* costs consist of four subelements

  - Occupational physical examinations, including lost time while the physical is administered

  - Medical surveillance

  - Lost time due to illness/injury as a result of hazardous materials

  - Industrial hygiene surveys.

- *Facilities* accounts for the cost of constructing and maintaining facilities especially for hazardous materials and hazardous waste.

- *Support Equipment* covers the cost of special equipment, including sensing devices and laboratory equipment, to handle hazardous materials and hazardous waste.

- *Emergency Response* accounts for the cost of emergency personnel and equipment to respond to hazardous materials and hazardous waste accidents, incidents and spills.

- *Disposal* encompasses the cost to operate an Industrial Wastewater Treatment Plant and to perform waste collection and handling, contractor disposal, and hazardous waste analysis and classification.

The application of these cost elements to the CBS/CDC is shown in the HAZMAT Evaluation Matrix included in section 7.2.4.

The HAZMAT model is built around the database of process and substance cost factors. To run HAZMAT, at least one process and at least one substance for the process must be selected from the database or entered by the user. To generate an estimate for an entire weapon-system life cycle, the user must enter data for all substances associated with each manufacturing and maintenance process for each HAZMAT Material Phase (i.e., Acquisition, Operating & Support, Disposal). The model has a limitation of 15 substances per process, however. This is a serious problem if the user is trying to estimate the total process cost. Most processes include more than 15 associated substances. For example, the

Depot Disassemble/Repair process for the F-16 has 210 associated substances. While it is possible to make several independent model runs, each with 15 substances, such an approach would require substantial labor time and costs. Additionally, errors would be introduced due to double-counting common activities and equipment, particularly personal protection and medical cost elements. Correction of these errors would require adjustments to the outputs of the model based on careful analysis of the printouts to identify and eliminate duplicate cost elements.

Table 7-2 contains excerpts from the Hazmat *User's Guide*, which provides a complete description of the model operation and comments by the Project Team on various aspects of the model operation.

EXCERPTS FROM THE HAZMAT USER'S GUIDE	PROJECT TEAM COMMENTS
The user has the option to Generate a New Estimate, Modify a Previous Estimate, View and/or Print Reports, enter a User Inflation Table, or Exit the Estimator.	1. HAZMAT does not offer an option to copy a file. The user can effectively copy a file by exiting HAZMAT and (in DOS or Windows) making a new directory and copying all of the files in the old directory into it. This new directory can then be selected for modification in HAZMAT.
[E]stimate general information, such as estimate title, date, estimate base year, cost input base year, discount rate, inflation table selection, and type of analysis, are entered. . . . With respect to the type of analysis, the user may choose to model the cost of hazardous materials for one subsystem for one year or the cost for hazardous materials throughout an entire phase in the life of the subsystem. Phase choices are: acquisition, operating and support, and decommissioning. Having entered the general estimate information, the user must select the system, type, subsystem, and phase for which the estimate is being done.... (Surface area is used to ratio from known systems in the Estimator database to the system being costed.) If the user had previously elected to compute the total phase cost, the number of systems, economic life (for operating and support phase only), and the number of subsystems per system, in addition to surface area, are requested.	2. Once this core information is entered and the file is saved, it cannot be changed. After entering the core information and all the process and substance information for the F-16, we were unable to change the number of systems. We were forced to start over and generate a new estimate. Therefore, to copy a file (as mentioned in the note above) is useless if any of the core information needs modification.
At this point, the software enters the process loop. The process orientation is one of the most unique features of the Estimator. In this loop, the user must select a process from the HAZMAT database, add a new process that is not in the the permanent HAZMAT database to the estimate database, modify a process that is currently in the estimate database, or delete a process that is currently in the estimate database. If the user elects to select a process from the permanent HAZMAT database, a list of processes associated with the system, type, subsystem and phase will appear on a scroll-type menu from which to choose. If the user elects to modify or delete a process that is currently in the estimate database, a scroll-type menu with all processes currently in the estimate database appears and the user must make a selection. Once the process of interest is identified for addition or modification, a series of process information screens will appear. The user can modify the database process information presented or accept the default values.	3. Selecting an analogous process for a weapon system not in the HAZMAT database is difficult if not impossible because the processes are not defined. For example, the AFA Depot Disassemble/Repair process has a default of 268 workers while the AFA Depot process has a default of 28. Without a definition of the process scope of work, the user will not be able to select the appropriate processes. 4. The processes for the F-16 and the F-15 are mixed together in the database. The user cannot distinguish between F-16 and F-15 processes. In our test run, we had to call TASC for the F-16 process numbers and look up the processes in the *System Administration Manual* in order to select only those processes associated with the F-16.

TABLE 7-2.—HAZMAT Operations and Project Team Comments

EXCERPTS FROM THE HAZMAT USER'S GUIDE	PROJECT TEAM COMMENTS
Once the process loop has been satisfied, the HAZMAT software moves to the substance loop. To facilitate cost trade-off analyses, substances are arranged in up to three groups with up to five substances each. One group would represent the baseline and the other two groups would then be alternatives. A cost comparison of the three groups is then presented in the HAZMAT output. The user has the option to use one, two, or all three of the groups. Within each group, the user can include between one and five substances. In the substance loop, the user can choose from among five options: • Add a unknown substance from the HAZMAT permanent database to the current group in the estimate. • Add a custom substance that is not in the HAZMAT permanent database, but has already been added to another group in the current estimate, to the current group in the estimate. • Add a custom substance which is not in the HAZMAT permanent database to the current group in the estimate. • Modify a substance, known or custom, that is already in the estimate database. • Delete a substance from the estimate database. For known substances from the HAZMAT permanent database, the user may choose from a list associated with the current process on a scroll-type menu. Known substances data can then be modified by the user. For custom substances being entered for the first time the user is offered a list of all known substances in the database so that one can be chosen as a starting point for the new custom substance or all substance-related data must be entered by the user. Entering a custom substance always requires the entry of the quantity used in the phase and process, disposal percentages, the occupational physical examination, and personal protection equipment required. In addition, for a custom substance created from "scratch," its name, cost unit of issue, and disposal costs and ratios must be input. Both known and custom substances can be used in the same group.	5. As noted previously, this limit of 15 substances per process is a serious problem if the user is trying to estimate the total process cost. 6. The substances are not defined in terms of chemical composition, toxicity, physical properties, or method of application (worker exposure). There are several substances with the same nomenclature (e.g., sealing compound, adhesive, enamel) that have radically different default values. For example, the Enamel identified as # 002867731 has a requirement for maximum personal protection equipment (resulting in a 30% loss of productivity) while the Enamel identified as # 005978231 requires no personal protection equipment.

TABLE 7-2.—HAZMAT Operations and Project Team Comments (contd)

EXCERPTS FROM THE HAZMAT USER'S GUIDE	PROJECT TEAM COMMENTS
After all substances, known and custom, have been entered for a process, the software returns to the process loop for any changes that may be necessary and then moves to the next decision point. If the user had originally selected the one subsystem for one year cost option, the HAZMAT software generates the costs for the twelve hazardous materials cost elements and returns to the main menu. If the user had originally selected the total phase cost option, some information on the phase schedule is requested. Once the schedule information is satisfied, the software computes the hazardous materials costs and returns to the main menu. At this point, the user has a number of choices. The most likely is to select the Print or View Reports option. Reports in a variety of formats can be displayed on the screen and can optionally be routed to a printer also.	7. The report options include: • Estimate Parameter List • Base Year Dollars • Then Year Dollars • Discounted Dollars 8. A report for each process and each substance within the process is provided. There is no summary report. To arrive at the total cost for a weapon system, the user must add together the costs in all of the process reports outside of HAZMAT. 9. There is no option to print out only the process report information. That is, the entire report including all of the substance information for each substance must be printed. 10. There appears to be a software bug in the report printing. On three occasions (and on two different machines) only about twenty of the processes in the file were printed out. We had to make four files with ten processes each to obtain print-out of all 36 processes included in the F-16 Operations & Support phase.
The user may also decide to Modify a Previous Estimate. If this option is exercised, the user must enter the path and subdirectory of the estimate to be modified. The Estimator flow then moves immediately to the process loop. From the main menu, the user could also select the User Inflation Table option. The estimator has provisions for two separate tables of inflation indices: default and user-defined.	11. Once this core information is entered and the file is saved, the information cannot be changed.

TABLE 7-2.—HAZMAT Operations and Project Team Comments (contd)

7.2.4 Application to the CBS/CDC

The Project Team performed a detailed analysis of each of the 12 HAZMAT cost elements and subelements to determine the basis of the equations and their application to the CBS/CDC. The results of this analysis are presented in the HAZMAT Detailed Evaluation Matrix in appendix A. The summary evaluation matrix is presented in figures 7-1, 7-2, and 7-3. As shown, the areas receiving the most coverage are the Environmental Program Management (CBS 1.0) and HTR Material Management (CBS 2.0) elements. The CBS depth score is a measure of the extent to which the model addresses the CBS element. Refer to chapter 4 for a description of the scoring convention used in these figures.

Each of the HAZMAT cost elements, with the exception of Loss of Productivity, is associated with a CBS element. There is no CBS element for loss of productivity because it is considered a cost driver, not an activity. Therefore, the HAZMAT cost element for the loss of productivity for wearing personal protection equipment is included in the CDC. In the summary evaluation matrix, the CDC element Productivity is shown as indirectly addressed for all the CBS elements addressed by HAZMAT. Because the HAZMAT algorithm estimates the cost for lost productivity for *all* work, the "work" estimated by HAZMAT includes not only those activities included in the CBS but also work that is outside of the CBS including the actual facility process operations (e.g., machining, disassembly) as depicted in figure 3-2.****

This broad scope of the HAZMAT cost element Personal Protection explains why it is one of the largest cost elements. According to the F-16 weapon system report, Personal Protection represents 30% of the total cost addressed in HAZMAT.

Potential Legal/Environmental Liability is another HAZMAT cost element that the Project Team considered to be a cost driver. It is shown in the evaluation matrix as the CDC element for Liability Damages Risk and Regulatory Compliance Risk. Because this cost element is a direct function of the CBS element Off-site Contractor disposal, it is shown there.

7.2.5 Model's Estimating Methodology

HAZMAT is best used to conduct trade-off studies at the process level to assess the relative cost impact of using alternative substances. The user may not be able to estimate a total process because of the model's limitation on the number of substances that can be selected per process. Our test run, discussed in section 7.2.6, shows that the user cannot estimate the total weapon-system cost with this version (3.1) of HAZMAT.

The HAZMAT algorithms operate at the substance and process level. Consequently, the input variables are also at this level. HAZMAT provides default values for all factors for each substance in a process. It estimates process cost by summing the estimated substance costs, applying process-level cost factors, and adjusting the resulting estimate by the surface-area ratio. This is where the limitation of 15 substances per process is critical. In short, HAZMAT estimates at a low level of detail and applies adjustments at a very high level. This methodology assumes that all of the processes in the database have a linear relationship to the surface area of the weapon system.

There are three basic algorithms in HAZMAT. They are discussed in the following sections.

****We recognize that the cost to perform the manufacturing and maintenance processes and the change in cost to perform the operation are of primary interest in a trade-off study (or point estimate), but for our purposes they are not considered environmental costs.

CBS Elements	CBS DEPTH SCORE 1 – 5	Cost Driver Categories: HTR Substances – Hazardous / Toxic	HTR Substances – Contact, Remote Radiological	Waste Sources – Mfg, Bases, & Depot Facilities	Waste Sources – Environmental Restoration Sites	Productivity – Personnel Protection Level	Cost Risk – Medic, Liabl, & Regulatory Risk	Cost Risk – Technology, & Scope Risk	Cost Risk – Cost Ranges, & Unknown Risk
1 Environmental Program Management									
.01 Program Management	4	\\\\\\\\\\\\	[ ]	\\\\\\\\\\\\	[ ]		////////		[ ]
.02 Program Support	3	\\\\\\\\\\\\	[ ]	\\\\\\\\\\\\	[ ]		\\\\\\\\\\\\		[ ]
2 HTR Material Management									
.01 HTR Material Management and Support									
.01 Pollution Prevention Program Implementation	0	[ ]	[ ]	[ ]		[ ]	[ ]	[ ]	[ ]
.02 Compliance Program Implementation	4	\\\\\\\\\\\\	[ ]	\\\\\\\\\\\\					[ ]
.02 HTR Material Control and Distribution									
.01 Requisition/Acquisition	4	\\\\\\\\\\\\	[ ]	\\\\\\\\\\\\					[ ]
.02 Handling/Distribution	5	\\\\\\\\\\\\	[ ]	\\\\\\\\\\\\		////////	////////		[ ]
.03 Management/Control of Use	4	\\\\\\\\\\\\	[ ]	\\\\\\\\\\\\					[ ]
.04 Recovery	5	\\\\\\\\\\\\	[ ]	\\\\\\\\\\\\		////////	////////		[ ]
.05 Reuse	0	[ ]	[ ]	[ ]		[ ]	[ ]		[ ]
.06 Recycle	5	\\\\\\\\\\\\	[ ]	\\\\\\\\\\\\		////////	////////		[ ]
.03 HTR Material Management Facilities									
.01 Personnel Protection	5	\\\\\\\\\\\\	[ ]	\\\\\\\\\\\\					[ ]
.02 HTR Capital Facilities/Equipment	5	\\\\\\\\\\\\	[ ]	\\\\\\\\\\\\				[ ]	[ ]

CBS Depth Score

- 0 ==> Cost tool does not address this CBS element.
- 1 ==> Cost tool addresses less than 10% of subordinate CBS elements.
- 2 ==> Cost tool addresses from 10% to 24% of subordinate CBS elements.
- 3 ==> Cost tool addresses from 25% to 49% of subordinate CBS elements.
- 4 ==> Cost tool addresses from 50% to 74% of subordinate CBS elements.
- 5 ==> Cost tool addresses more than 75% of subordinate CBS elements.

CDC Application

- ==> No box indicates the CDC cell is not applicable.
- [ ] ==> Cost tool does not address this CDC cell.
- //////// ==> Cost tool indirectly addresses this CDC cell.
- \\\\\\\\\\\\ ==> Cost tool directly addresses this CDC cell.

FIGURE 7-1.—HAZMAT Evaluation Matrix: Coverage of CBS Elements 1 and 2 and CDC

CBS Elements			CBS DEPTH SCORE 1 – 5	Cost Driver Categories: HTR Substances: Hazardous / Toxic	HTR Substances: Contact, Remote Radiological	Waste Sources: Mfg, Bases, & Depot Facilities	Waste Sources: Environmental Restoration Sites	Productivity: Personnel Protection Level	Cost Risk: Medic, Liabl, & Regulatory Risk	Cost Risk: Technology, & Scope Risk	Cost Risk: Cost Ranges, & Unknown Risk
3 HTR Waste Management											
.01		HTR Waste Operations Management and Support									
	.01	Pollution Prevention Program Implementation	0	☐	☐	☐		☐	☐	☐	☐
	.02	Compliance Program Implementation	0	☐	☐	☐		☐	☐		☐
.02		On–site Waste Management Facility Construction/Ops									
	.01	Treatment Facility Design & Construction	0	☐	☐	☐				☐	☐
	.02	Treatment Facility Operations & Equip. Maint.	0	☐	☐	☐		☐	☐		☐
	.03	Storage Facility Design & Construction	0	☐	☐	☐				☐	☐
	.04	Storage Facility Operations & Equip. Maint.	0	☐	☐	☐		☐	☐		☐
	.05	Disposal Facility Design & Construction	0	☐	☐	☐				☐	☐
	.06	Disposal Operations & Equip. Maint.	0	☐	☐	☐		☐	☐		☐
.03		Closure and Post–Closure Care									
	.01	Treatment Facility Closure	0	☐	☐	☐		☐	☐		☐
	.02	Storage Facility Closure	0	☐	☐	☐		☐	☐		☐
	.03	Disposal Facility Closure	0	☐	☐	☐		☐	☐		☐
	.04	Restoration	0								☐
	.05	Certification of Closure	0						☐		☐
	.06	Post–Closure Care	0								☐
.04		Off–site HTR Waste Disposal									
	.01	Commercial (Fee)	5	\\\\\\\\\\	☐			//////////	\\\\\\\\\\		☐
	.02	Other than Commercial (Fee)	0	☐	☐			☐	☐		☐

CBS Depth Score

0	= = > Cost tool does not address this CBS element.
1	= = > Cost tool addresses less than 10% of subordinate CBS elements.
2	= = > Cost tool addresses from 10% to 24% of subordinate CBS elements.
3	= = > Cost tool addresses from 25% to 49% of subordinate CBS elements.
4	= = > Cost tool addresses from 50% to 74% of subordinate CBS elements.
5	= = > Cost tool addresses more than 75% of subordinate CBS elements.

CDC Application

	= = > No box indicates the CDC cell is not applicable.
☐	= = > Cost tool does not address this CDC cell.
//////////	= = > Cost tool indirectly addresses this CDC cell.
\\\\\\\\\\	= = > Cost tool directly addresses this CDC cell.

FIGURE 7-2.—HAZMAT Evaluation Matrix: Coverage of CBS Element 3 and CDC

CBS Elements	CBS DEPTH SCORE 1 – 5	HTR Substances: Hazardous / Toxic	HTR Substances: Contact, Remote Radiological	Waste Sources: Mfg, Bases, & Depot Facilities	Waste Sources: Environmental Restoration Sites	Productivity: Personnel Protection Level	Cost Risk: Medic, Liabl, & Regulatory Risk	Cost Risk: Technology, & Scope Risk	Cost Risk: Cost Ranges, & Unknown Risk
4 Environmental Restoration/Corrective Measures									
.01 PA/SI and/or RFA	0								
.02 RI/FS and/or RFI/CMS	0								
.03 Remedial Design	0								
.04 Remedial Action and/or Corrective Measures									
Preparatory	0								
On-site Containment / Collection	0								
Treatment	0								
Decontamination & Decommissioning	0								
Off-site Treatment/Disposal	0								
Physical Completion / Closure	0								
5 HTR Material and Waste Transportation									
.01 Transportation Management	0								
.02 Transportation	4								

CBS Depth Score

0 ==> Cost tool does not address this CBS element.
1 ==> Cost tool addresses less than 10% of subordinate CBS elements.
2 ==> Cost tool addresses from 10% to 24% of subordinate CBS elements.
3 ==> Cost tool addresses from 25% to 49% of subordinate CBS elements.
4 ==> Cost tool addresses from 50% to 74% of subordinate CBS elements.
5 ==> Cost tool addresses more than 75% of subordinate CBS elements.

CDC Application

==> No box indicates the CDC cell is not applicable.
==> Cost tool does not address this CDC cell.
==> Cost tool indirectly addresses this CDC cell.
==> Cost tool directly addresses this CDC cell.

FIGURE 7-3.—HAZMAT Evaluation Matrix: Coverage of CBS Element 4 and CDC

7.2.5.1 HAZMAT Algorithm Based on Quantity of Substances

The HAZMAT algorithm based on the quantity of substances uses equations in the form:

COST = SURFACE RATIO* X QUANTITY OF SUBSTANCE USED** X [Factor for Cost per Pound of Substance Used].

The following cost elements use *process-level* factors for cost-per-pound of substance used.

- Transportation
- Management
- Handling
- Potential Legal/Environmental Liability
  - Contractor-Disposed Waste Liability
  - Hazardous Air Emissions Liability
- Facilities
- Support Equipment
- Emergency Response
- Disposal: Hazardous Waste Analysis/Classification.

The rationale for the development of these factors is not documented. It is not clear how the factors (e.g., management cost per pound of substance used) at the process level were developed from the annual facility cost contained in the weapon systems reports.

This HAZMAT algorithm is not sensitive to substance type. The toxicity or physical characteristics (e.g., flammable, reactive) of the substance does not affect the cost estimate for these elements. This may be problematic when conducting a trade-off study between alternative substances.

The following cost elements use *substance-level* factors for cost-per-pound of substance used.

- Procurement (Note: Procurement is a function of cost per unit of measure [weight, volume, or quantity])

- Disposal

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*SURFACE RATIO = SURFACE AREA ESTIMATE/SURFACE AREA CORE where

- SURFACE AREA ESTIMATE = User-entered variable defining the surface area in square feet. The *Hazardous Materials Life Cycle Estimator User's Guide Version 3.1* defines square feet as, "the total outside surface feet of the subsystem being evaluated."

- SURFACE AREA CORE = Surface area in square feet of the reference subsystem in the Estimator.

**The quantity of the substance used per subsystem per year in the selected process expressed in terms of unit of issue.

- Industrial Waste Treatment Plant
- Contractor Disposal
- Analysis/Classification
- Recycle
- Air Emissions.

Because these factors are at the substance level, they are sensitive to the specific substance being purchased or disposed.

7.2.5.2 HAZMAT Algorithm Based on Estimated Number of Workers

The second basic HAZMAT algorithm uses a conventional bottoms-up estimating approach. It is based on an estimate of the number of workers, the duration of the task, and the related cost (e.g, wage rates and material costs). As with the Quantity of Substance algorithm, the estimates are based on data at the process and substance level; they are not, however, adjusted by the ratio of surface area. To arrive at the total process cost, the resulting estimate must be multiplied by the number of subsystems and weapon system's life-cycle years.

7.2.5.3 HAZMAT Algorithm Based on EPA Cost Factors

The third basic HAZMAT algorithm employs factors from the *Pollution Prevention Benefits Manual* (October 1989), prepared for the EPA by ICF Incorporated, to estimate the Potential Legal/Environmental Liability cost element (and all subordinate cost elements). The developers of HAZMAT also cite a TASC Technical Information Memorandum as part of the basis for this algorithm. The basis and rationale in the documents referenced by the developers are not described, however.

This algorithm includes variables for the percentage of hazardous material disposed of through a contractor, a dilution ratio to estimate the total disposal quantity, and a potential-liability-cost-per-pound factor from the cited EPA study. This factor is the sum of factors for each of the following subordinate elements:

- Toxic Torts
- Regulatory Authority Correspondence
- Real Property Damage
- Contaminated Water Treatment
- Natural Resources Damages.

This algorithm also includes a cost factor for court fines and penalties and an equation for Potential Legal/Environmental Liability associated with air emissions. The source for this equation is a TASC technical information memorandum.

HAZMAT provides complete access to all of the cost factors, labor rates, and unit-cost information. The user can, therefore, customize the estimate to specific conditions. HAZMAT includes an escalation feature to calculate base-year (constant) dollars, then-year dollars, or discounted dollars. It does not provide a place to include profit (or fee), overhead or indirect factors, or factors affected by whether the work is being performed by Government, prime contractor, or subcontractor personnel.

7.2.6 Evaluation Test Run

The Project Team ran an estimate for the entire F-16 Operations and Support phase to test the HAZMAT model results against F-16 cost reported in the weapon system report, *Hazardous Materials Management Life Cycle Cost Model Phase I* (March 31, 1991). We matched the model inputs to the reported F-16 assumptions to the extent possible. The following inputs were used:

- General Estimate Information
  - Estimate base year = 1991
  - Inflation Table = Default
  - Number of Work Hours in 1 Year = 2080
  - Type of Analysis = Total Phase Cost
  - System Name = Aircraft
  - System Type = Fighter
  - Subsystem Name = Airframe[a]
  - Number of Subsystems per System = 1
  - Surface area of Subsystem = 1500 (model default)
  - Phase Name = Operating & Support
  - Number of Systems Supported = 68[b]
  - Number of Operating Locations = 21[c]
  - Program Maintenance Schedule = 4.0[d]
  - Economic Life, in years, of Subsystem = 20

- Process-Level Inputs

  All F-16 processes included in the HAZMAT database were selected, and the default information for each was accepted.

- Substance-Level Inputs

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[a]Airframe is the only subsystem selection that includes F-16 processes. This selection is not limiting because all F-16 subsystem processes (e.g., Emergency Power Unit Overhauling, Electronic Warfare) are included. It is assumed that these processes represent all F-16 processes included in the weapon system report. Of course, the analyst would need to verify such an assumption for any estimate of a system not in the database.

[b]Calculate 68.23 (round to 68) aircraft per location given a total of 1433 aircraft and weighted number [see footnote c] of locations of 21.

[c]The weighted number of locations = 13 (Operational Bases) + 1/3 * 24 (Air National Guard [ANG] Bases)= 21. This method of adjusting the number of locations, to account for the fact that operational bases have three squadron and ANG bases have only one, was taken from the validation report.

[d]The program depot maintenance schedule is the number of years between visits to the depot for a single system.

The first 15 substances for each process were selected. All 15 were selected under group 1.*

The results of this test run are presented in table 7-3.

TABLE 7-3.—F-16 Weapon System Test Run Results

Process Number	Process Name	Test Run	Reported Cost	% Delta (Test - Report) / Report
36	F-16 Weapon System Total			
Cost Element		FY91 $(000)	FY91 $(000)	
Disposal		2,481	29,060	-91
Emergency Response		5,312	2,820	88
Facilities		77,228	31,113	148
Handling		7,117	40,620	-82
Management		144,661	24,360	494
Medical		27,375	58,660	-53
Personal Protection		553,231	191,860	188
Potential Liability		16,998	103.112	84
Procurement		18,451	141,240	87
Support Equipment		2,017	7,706	74
Training		417	13,608	97
Transportation		4,042	2,180	85
Total		**859,330**	**646,339**	**33**

There are several reason for the great disparity between the costs reported in the F-16 weapon system report and the results of the test run. Some of the following reasons tend to drive the estimated cost up while others tend to drive it down. The Project Team could not reconcile the differences between the estimate and the reported cost. Our test run revealed the following:

- Only 15 substances could be entered for processes, many of which require substantially more than 15 substances. Because several of the equations are a direct function of the quantity of substances, this limit may account for a great portion of the difference.

- The F-16 weapon system report identifies costs for hydrazine training, hydrazine facility costs, and hydrazine emergency response. However, the HAZMAT model does not appear to address these costs; the substance database does not include hydrazine, and the training factors, facility-cost-per-pound factors, and emergency-response factors are the same in HAZMAT for both F-15 and F-16 processes despite the fact that hydrazine is not used for the F-15 weapon system.

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*The Project Team contacted TASC to verify that the use of 15 substances in one group would not present an estimating error. Recall the stated limit for each of the three groups is five. The Project Team used this approach to maximize the number of substances that could be selected for a given process.

- In our test run of the F-16 data, we came across an apparent input error for the corrosion-control process. The model calculated the cost at several billion dollars. One possible explanation is that the default quantity of the substances is very large. For example, the quantity for paint remover is 457 drums each with a weight of 440 pounds (55 gallons * 8 [pounds per gallon]) for a total of 201,080 pounds. Because we did not have an appropriate quantity to use, we excluded this process from our test run.

- There is a programming error for AFA Depot Chemical Mill/Bond (process #17). The HAZMAT model would not accept this process selection.

- Each process is treated as a separate and distinct entity. The cost estimate for a given process is not affected by the number of processes being estimated. Therefore, if a worker dons protective equipment to perform more than one process concurrently (or sequentially), the model assumes that he will have to take time to acquire the protection equipment, don it, take it off, and return it for each process. In this way, the model may be overestimating the loss of time for personal protection.

- The HAZMAT algorithms estimated the cost for all 12 cost elements for base-level processes, despite the fact that the F-16 report had no cost factors at the base level for the following cost elements:

  - Training (four of the six training courses are depot-level only)

  - Handling

  - Facilities (no base-level facility costs were reported, but there was a reported support-equipment cost)

  - Disposal (IWTP operations cost, Waste Collection/Handling cost, and Hazardous Waste Analysis/Classification).

- HAZMAT estimates cost for Recycling and Air Emissions, but the F-16 weapon system report did not mention any such costs.

In consideration of the HAZMAT development methodology, the Project Team suspected that the model would be sensitive to manufacture and/or maintenance facility conditions. To test this sensitivity, a single process and substance for a single year was run twice changing only the System Type. Parameters for each run are shown in table 7-4.

Table 7-5 shows the results of this sensitivity analysis.

We attribute the difference in cost between these two estimates to a difference in facility conditions. The basis for the HAZMAT default cost factors is the historical cost collected

TABLE 7-4.—Facility Conditions Sensitivity Test: First and Second Run Parameters

	RUN #1	RUN #2
System Name	Air Craft	Air Craft
System Type	Cargo	Bomber
Subsystem Name	Airframe	Airframe
Phase Name	Operating & Support	Operating and Support
Process	Depot Stripping	Depot Stripping
Depainting Flag	P (depainting method)	P (depainting method)
Substance	Paint Remover	Paint Remover
Surface Area	13,000 ft^2	13,000 ft^2
Number of Direct Personnel	25	25

TABLE 7-5.—Sensitivity of Process to System-Type Selection

HAZMAT Cost Elements	Run #1 FY 1991 $	Run #2 FY 1991 $	% Delta (Run #1 - Run #2) / Run #2
Disposal	1,070	330	224
Emergency Response	0	0	
Facilities	0	16,400	-100
Handling	180	360	-50
Management	4,830	3,010	60
Medical	31,540	10,250	208
Personal Protection	316,550	459,720	-31
Potential Liability	3,200	1,130	183
Procurement	1,560	550	184
Support Equipment	0	190	-100
Training	0	510	-100
Transportation	0	30	-100
Total	**358,930**	**492,480**	**73**

from the specific facilities. Facility conditions include the overhead assigned to the process in question, the facility business base (high/low volume of business for the year of cost basis), and the portion of the facility cost allocated to the subject weapon system.

This outcome implies that the user must be familiar with the associated facility conditions underlying the database when accepting the default values for a process or substance. The user also must be familiar with the facility conditions associated with the estimate being developed. The weapon system reports often provide the total facility annual cost and the portion of that cost allocated to the weapon system. However, the user will likely need more information regarding overhead factors and other cost-driving considerations. The user also

will need to know how the cost data are translated to the cost factors provided in the database.

7.2.7 Conclusions/Recommendations

7.2.7.1 Conclusions

HAZMAT addresses an important part of the EM life cycle: HTR Material Management. The internal database and the weapon system reports provide a valuable source of information regarding environmental costs at the manufacturing, operational bases, and depot facilities. However, our evaluation shows that the current version of the model falls short of its stated objectives. As noted previously, the *Model Validation Report* states, "The purpose of the model [is] to provide a tool for hazardous material evaluation and to estimate the total cost of employing hazardous materials in Air Force weapon systems." The *User's Guide* notes, "The system is designed for System Program Office (SPO), contractor, and repair depot personnel to assess the cost of using hazardous materials in current and future weapon systems." HAZMAT may be useful in conducting trade-off studies between alternative substances used for specific process operations, but it will not provide the user with the total weapon system environmental LCC.

The SPO or cost analyst should exercise caution in using the HAZMAT model to conduct trade-off studies. Specifically, unless the factors such as facility cost per pound of substance used can be entered with certainty, the estimates can provide only relative-cost comparisons. Also, because some of the process-level factors are insensitive to the type of hazardous material used, a trade-off study between alternative substances may not provide a complete assessment.

Because the HAZMAT model requires substance- and process-level data, the full design of a weapon system (or at least the processes) will be required. Therefore, the HAZMAT model will not likely be useful in the early life-cycle phases. In short, the current version of HAZMAT has its greatest utility for conducting relative-cost trade-off studies between alternative processes and/or substances from the late phases of development through weapon system decommissioning.

7.2.7.2 Recommendations

The Project Team recommends the following improvements to the HAZMAT model.

1. Document the basis of the HAZMAT model. Document the development of cost factors from their cost basis in weapon system reports.

2. Develop a capability to quickly generate weapon-system- and -subsystem-level estimates. Estimates for weapon systems already in the database should be easily reconcilable to the cost basis. Cost data associated with the subject weapon system should be easily discernable as opposed to the mixture of data in the F-15 and F-16 processes.

3. Develop a process dictionary to fully describe the operations and scope of each process. Group these processes into classifications sharing similar hazardous material requirements, personal protection requirements, and/or hazardous-waste generation characteristics.

4. Develop generic process operations for each classification established in suggestion 3. Provide a mean and standard deviation for factors included in the generic process.

5. Develop a substance dictionary to fully describe each substance in the database. Group these substances into classifications sharing similar characteristics (e.g., toxicity, physical properties, personal protection requirements).

6. Document facility conditions including overhead rates, business base, existing facilities (material handling, treatment, storage, and disposal). Using this information, reconcile the difference between facility costs in the database (e.g., the difference between the cargo plane and the bomber cost in the test run above).

7. Develop CERs based on the characteristics (e.g., toxicity, physical properties) of the substance to estimate affected cost elements (see the discussion on the first algorithm in section 7.2.5.1).

8. Develop a cost report that delineates direct cost and indirect costs and provide a place for the user to input estimating factors including:

   - Distribution of Work
     - Government (work performed by Government employees)
     - Contractor
       - percent of work performed by prime contractor
       - percent of work performed by subcontractor
     - Subcontractor's overhead rate
     - Subcontractor's G&A and profit rates
     - Prime contractor's overhead rate
     - Prime contractor's G&A and profit rates
     - Other (e.g., taxes, permit fees).

9. Enhance report capabilities to provide weapon-system-level and subsystem-level summary reports.

10. Allow the user to modify the core information rather than having to start over to generate a new estimate (see the Project Team's comment #2 in table 7-1).

11. Collect data for additional years on the systems already in the database to:

    - Provide evidence that the steady-state assumption is valid or that year-to-year variability is important

- Collect data, to the extent feasible, for CBS and CDC elements not addressed in the current version of HAZMAT.

12. Collect data on additional systems.

Additional recommendations are discussed in the Chapter 6 Short-Term/Long-Term Plans.

7.3 EM COST TOOL EVALUATIONS: HCAS, RACER-ENVEST, AND MCACES

HCAS, RACER-ENVEST, and MCACES address CBS 4.0 Environmental Restoration/ Corrective Measures. These estimating systems have complementary estimating capabilities. HCAS provides project-level historical cost data. The RACER-ENVEST model provides a parametric estimating capability, and MCACES provides a detailed unit-cost database and bottoms-up estimating capability. Together these systems provide a powerful estimating capability for CBS 4.0 that is years ahead of cost models that address other EM areas (particularly CBS 2.0 and 3.0). The systems are, however, the least likely to be needed in the MDAP LCC because if the environmental program management activities are performed properly, no ER (or corrective measures) will be required.

The most direct application of these models/databases arises when estimating the weapon-system-related facility closure and post-closure care. Many of the ER technologies have application for RCRA closure and post-closure activities. Additionally, these cost models/databases may prove useful in establishing an upper bound of EM cost risk. For instance, because paying the fines imposed for environmental damages and performing full cleanup is certainly the most expensive EM alternative, this cost-risk estimate is by far the most conservative for dealing with HTR materials and waste.

The evaluations of HCAS, RACER-ENVEST, and MCACES are presented together because they are closely related to each other in that they all use the ICEG ER WBS. The abstract, methodology, and organization/operation of each are addressed individually, but the application to the CBS/CDC, Evaluation Test Run, and Conclusions/Recommendations sections are combined.

7.3.1 HCAS: Abstract

At the time ICEG developed HCAS, the group was chaired by a representative from the Navy HQ, LANTNAVFAC-ENGCOM; there was professional representation from several Government agencies including DoD (principally the Army, Navy, and Air Force), DOE, and EPA. The latest release of HCAS, version 2.0 (October, 1994), was evaluated.

HCAS was developed to provide a readily accessible, comprehensive, historical cost database for ER projects. HCAS currently addresses only Remedial Action (CBS 4.4) projects but is expected to be expanded to include all elements under Environmental Restoration (CBS 4.0). It is intended to contain sufficient technical and cost information on projects to be useful as a budget-development tool. The user can quickly find analogous projects through a user-

friendly data-query system. To facilitate these queries, Category Codes have been established to classify projects by cost drivers. The five Category Codes are:

- Waste Location (e.g., landfills, waste piles, groundwater)
- Technical Approach (e.g., on-site containment/collection, off-site treatment)
- Summary Level WBS (e.g., site work, surface water collection and control)
- Contaminated Media (e.g., solid rock, sludge, water/other liquid)
- Waste Type (e.g., hazardous, hazardous & radioactive [non-transuranic]).

Only nine projects are loaded into HCAS Version 2.0, but it is anticipated to grow to nearly 100 projects by FY 1996. The project information includes specific project scope and regulatory requirements, technology, construction and operation costs, circumstances or conditions affecting the project, contracting scenarios, and other cost drivers.

7.3.2 HCAS: Database Development Methodology

Databases containing historical construction-cost databases were used as the prototype for the basic HCAS database structure, but several other considerations led to the final structure. These factors included, cost and technical information suggested by ER legislation (e.g., CERCLA and RCRA), environmental regulation, specific cost-estimating requirements, and data-collection limitations. The result is a historical project cost-collection system that requires minimal input to extract useful data. HCAS does not normalize or manipulate data. It simply provides the user with information to be analyzed. A cost-estimating and -analysis system, the Environmental Bottom-up Cost Estimating System (EBUCES, version 1.0 released in October, 1994) has been developed by ARINC Research Corporation specifically to analyze data obtained from HCAS. (EBUCES was not available in time to evaluate for this report.)

All of the agencies involved in the ICEG have agreed to submit data in accordance with the HCAS structure. To facilitate obtaining useful and accurate historical project cost information, some DoD services are requiring their prime contractors to prepare an estimate based on the ICEG WBS upon contract award. The contractor also is required to report actual cost data as the project reaches specified milestones and at completion. According to the ICEG guidelines, each agency must have a data quality check performed at a designated data screening center. The data are then sent to a central repository for a final screening and incorporation into the HCAS database. The central repository is currently the Logistics Management Institute in McLean, Virginia. The HCAS database is updated quarterly and distributed to subscribers on CD ROM by the National Institutes of Building Sciences.

7.3.3 HCAS: Database Organization/Operation

HCAS version 2.0 runs on IBM PCs and compatibles with a minimum configuration of: 80286 processor, 3MB of hard drive space, 4MB of RAM, and MS-DOS version 3.3 or higher. HCAS features pop-up lists, pull-down menus, mouse support, and on-line help.

There are five hierarchical levels of data in HCAS. The HCAS users manual describes them as follows:

- The *Contracts* level contains the information necessary to identify the contracting mechanisms for a set of projects.

- The *Projects* level contains information related to each site.

- The *Phases* level contains information about the cost engineer's concept of the project at given points in time. These points are generally the Estimate (the final estimate before the project is awarded), Award (the Contract award), and Actual (final cost at completion of remediation).

- The *Tasks* level contains information about the actual work that must be performed to complete the project. Each Task groups all those actions in the same Waste Location (e.g., landfill or underground storage tank [UST]) that share the same Work Breakdown Structure Summary Level number. The WBS is a list of all Tasks performed in HCAS work that has been standardized by several Government agencies. The entire structure down to the fifth level of detail is contained within HCAS.

- The *Details* level contains the detailed information about the actions performed in each Task. At this level, the user may enter a description of the work performed and may be as general or as detailed as necessary among the third, fourth, and fifth levels of the Work Breakdown Structure.

7.3.4 RACER: Abstract

RACER comprises an expert system called the Remedial Action Assessment System (RAAS) and a cost-estimating model called ENVEST. RAAS identifies applicable ER technologies for given site and contamination conditions, and ENVEST estimates the associated cost. Only the cost model (ENVEST) is evaluated in this report. RACER-ENVEST was developed by Delta Research Corporation under contract to the Air Force Civil Engineering Support Agency (Tyndall Air Force Base). The latest release, version 3.0 (November 1994), was evaluated.

RACER-ENVEST was designed to produce objective, consistent, and reasonably accurate estimates at early phases of ER projects and progressively more detailed and defensible estimates as project definition increases.

RACER-ENVEST is an engineering-design-based model largely developed through a reverse engineering process based on a detailed design and the associated unit costs and quantities of selected projects. The unit costs and quantities for each project type are modeled and parameters established in order to extrapolate or interpolate the quantities and costs. The user enters the required parameters, and the model calculates (through an extrapolation/ interpolation process) quantities and unit costs and produces an inferred design detail. A model based on this methodology (a design calculated from project parameters) is sometimes referred to as a parametric design model.

The resulting estimate is based on the extrapolation or interpolation of the original project quantities according to the changes in the required parameters. RACER-ENVEST also provides the user with the ability to change any of the quantities or unit costs in the estimate.

7.3.5 RACER-ENVEST: Methodology

The specific projects used as the basis for RACER-ENVEST are not documented, but many of the major cost components or assembly bases are documented in the help screen information. The equations and algorithms used to calculate assembly quantities and cost from detailed unit information are available to Government agencies offline but are in the software or its documentation. The user probably will not miss this back-up information, however, because the default assembly quantity and cost information have sufficient design detail. RACER-ENVEST version 3.0 includes individual models for the RI/FS process, the RCRA Facility Investigation/Corrective Measures Study (RFI/CMS) process, and several specific remedial technologies as indicated in the RACER-ENVEST Detailed Evaluation Matrix in appendix A.

Each of these internal models requires general project information and parameters (e.g., well depth, diameter, drilling process casing material) to run. Based on these inputs, a default design is generated and assembly quantities and costs are calculated from the internal algorithms. Secondary parameters are available to better define the project and consequently the default design.

7.3.6 RACER-ENVEST: Organization/Operation

RACER-ENVEST version 3.0 operates in the Windows environment and runs on an IBM or compatible PC with a minimum configuration of: 80386 processor, 30MB of hard drive space, 4MB of RAM, 3.5" floppy disk drive, and Windows version 3.1 or higher.

The following information, from the RACER *Model Report* (May 10, 1993), describes the six basic steps included in the RACER-ENVEST estimating process.

- Project Definition: Project Definition consists of general information about the project at both the project and site level.

  - Project-level information includes

    - Project identification
    - Location studies and site options
    - Project name
    - Comments
    - Preparer's name
    - Date of estimate.

  - Site level information includes

    - Site identification
    - Site category
    - Site name
    - Comments
    - Preparer's name
    - Date of estimate.

Studies, site options, and site category segregate tasks within a project to avoid duplication of effort and costs. The location identification determines the location cost modifiers, which adjust the labor, material, and equipment costs by area cost factors. The assembly costs are based on the U.S. Army Corps of Engineers (USACE) Unit Price Book (UPB) national unit price database. Unit prices in Atlanta, Georgia, serve as the reference data for prices in other locations.

- Phase Identification: The RACER-ENVEST system consists of separate models for each phase of remediation: RI/FS or RFI/CMS, RD, and RA. The RA models include activities/costs for Operations & Maintenance and other post-project activities. Costs can be estimated for one or more phases of a project within a single estimate.

- Technology/Treatment Train Identification (RA only). The RA cost model is actually a collection of independent cost models, each specific to a particular technology. To generate an RA cost estimate, the technology or group of technologies (i.e., a treatment train) must be identified. This can be accomplished by using RAAS, field notes from RI/FS or RFI/ CMS, or other traditional methodologies to determine the applicable treatment train for the site in question.

- Model Processing: Cost estimates are generated by processing each of the models that have been identified for the project. All of the models within the RACER-ENVEST system are based on the parametric modeling methodology, which has four basic steps

  - Required Parameters: The minimum amount of information required to create a cost estimate.

  - Secondary Parameters: Secondary parameters have defaults determined by the model. The defaults are dictated by the engineering design and model assumptions. A reasonable cost estimate can be created using only the required parameters. However, if more detailed information is known, the secondary parameters can be modified to create a more precise and site-specific estimate.

- Assembly Quantities: Computed using the parameter values, engineering design, and assumptions.

- Assembly Costs: Computed using the assembly quantities and the adjusted assembly costs. The basic assembly costs include the costs of labor, equipment, and materials and are the sum of the assembly line item costs for Atlanta, Georgia, taken from the USACE UPB. These costs are first adjusted to reflect pricing at the specified site by applying the location cost factors, which are determined by the required parameter: Location. Costs are further adjusted to account for the reduced level of productivity associated with safety level requirements.

RACER-ENVEST also allows the user to input other standard estimating information through the "Cost Modifiers" routine. These cost modifiers are: Contractor Indirect Overhead and Profit, Escalation, Contingencies, and Project Management.

7.3.7 MCACES: Abstract

Building Systems Design Inc. under contract to the USACE, developed MCACES. The latest version, 5.30, was evaluated. The system has been used for several years, principally by the USACE, for estimating virtually all types of construction projects. The database contains over 20,000 line items of construction-cost data. The Army, in cooperation with DOE, has added more than 4,000 line items dealing with HTR Waste (HTRW) remedial action (e.g., respirators, tyvek suits).

MCACES is a unit-cost model and database that is used primarily for construction-project-type estimates using a quantity take-off (or bottom-up) estimating methodology. A project design that is at least 30% complete is required to use MCACES. The engineering design and assumptions are used by the cost engineer to determine the quantity of units including the required crew mix, equipment, and materials. The Unit Price, Crews, Labor Rate, and Equipment databases provide most of the required pricing information.

7.3.8 MCACES: Methodology

MCACES is organized according to both a civil construction WBS and the ICEG's HTRW RA WBS. While the principal use of MCACES is for developing quantity take-off estimates, it can also be used at earlier design phases, even at the conceptual design phase, provided an internal "model" of the project type exists. MCACES models work in a manner similar to the RACER-ENVEST models. However, all of the estimating equations and algorithms are available to the user. Because MCACES contains a detailed database, it provides more analytical flexibility than RACER-ENVEST but requires more training and, generally, more data.

7.3.9 MCACES: Organization/Operation

MCACES runs on an IBM or compatible PC with a minimum of 530Kb of RAM available for program use. It requires approximately 8.5MB of hard disk space. The supporting databases use varying amounts of additional disk space:

- Projects database: 16Kb–1,540Kb
- Models database: 397Kb–4,155Kb
- Assemblies database: 7,593Kb–9,168Kb
- National UPB database: 12,327Kb
- National Crews database: 935Kb
- National Labor Rates database: 47Kb
- Equipment Rates database: 2,552Kb.

MCACES is designed to be used in the MS DOS (version 3.3 or higher) environment without a mouse.

The following points, adapted from the *MCACES Gold Volume I User Manual* for version 5.3, describes the seven MCACES databases.

- The *Project database* is the work area where the estimate is actually developed. All other databases are used to store data items that can be incorporated into an estimate by copying them to the Project database.

- The *Models database* provides a library of previous projects that can be easily used to create new projects. The previous projects can be linked in a way that the user need make only minimal adjustments to quantities.

- The *Assemblies database* is used to group cost items into sets or assemblies, which represent all the costs required to create a larger piece of a project. For example, an assembly representing a specific type of concrete slab might include cost items for the compacted gravel fill, vapor barrier, wire mesh, concrete, edge form, and finish. Using assemblies can reduce the amount of data that has to be entered for each new project. Assemblies serve as one form of input into the Project database and also can be used to construct models for the Models database.

- The *Unit Price database*, based on the USACE UPB, contains individual cost items, each with its own material, labor, and equipment costs; crew identification reference; and crew output figures. As appropriate, shipping weight and shipping volume for individual items also are stored.

  The Unit Price database organizes cost items under a hierarchy of titles that corresponds to the Construction Specifications Institute classification system. The user can supply another database and classification scheme. Cost items from the Unit Price database can be copied into the Project, Models, or Assemblies databases.

- The *Crews database* groups labor and equipment costs into crews. The user may create an alternative database.

  Crews stored in this database can be referenced by cost items in the Project, Models, Assemblies, or Unit Price databases. Crews also can be copied directly into the Project database for such tasks as mass excavation on civil works projects.

- The *National Labor Rates database* stores hourly costs for different trades. These costs include taxes, insurance, overtime, fringe benefits, and travel. Differentials for foreman costs and apprentice costs are provided. The Labor Rates database provides labor-cost information to the Crews database. Labor-rate items (i.e, tradesmen) also can be copied directly into the Project, Models, or Assemblies databases as individual cost items.

- The *Equipment Rates database* stores unit equipment costs for the most common types of equipment found on many projects. Its use by the program is similar to that of the Labor Rates database. Cost data can be referenced by the Crews database, and cost items also can be copied directly into the Project, Models, and Assemblies databases.

7.3.10 Application of HCAS, RACER-ENVEST, and MCACES to CBS/CDC

Individual evaluation matrices for HCAS and MCACES are not needed because the nature of each matrix can be summarized in a few sentences. An evaluation matrix for HCAS would show that HCAS is potentially applicable to CBS 4.4 (and its subordinate elements) and to all CDC elements. As noted, HCAS currently has only 9 projects loaded but is expected to grow to nearly 100 by FY 1996. Therefore, an HCAS evaluation matrix depicting loaded historical cost information would quickly become nonrepresentative.

Similarly, an evaluation matrix for MCACES would show that it too is potentially applicable to CBS 4.4 and all of its subordinate elements and to all CDC elements. MCACES can be used to estimate virtually any RA project provided the design detail is sufficient. Version 5.30 includes assemblies in the HTRW RA Assemblies database that are examples of commonly used remedial technologies. Version 5.30 includes models for the CBS elements shown in boldface in figure 7-4.

Figures 7-5, 7-6, and 7-7, evaluation matrices for the RACER-ENVEST model, show the range and depth of coverage that it provides. As shown in these figures, RACER-ENVEST has application to CBS 3.03 Closure and Post-Closure Care and CBS 3.04 Off-Site HTR Waste Disposal. This is a valuable estimating capability for cost estimators/analysts developing MDAP

MCACES Version 5.30 models the CBS elements shown in boldface below.

4.04 HTRW Remedial Action

.02 On-Site Contamination/Collection

.02 Groundwater Collection & Control

.01 Extraction & Injection Wells
.03 Slurry Walls

.04 Solids Collection & Containment

.05 Capping Contaminated Areas/Waste Piles

.06 Drums/Tanks/Structures/Misc. Demolition

.01 Drum Removal
.02 Tank Removal

FIGURE 7-4.—CBS Elements Modeled in MCACES Version 5.30

CBS Elements	CBS DEPTH SCORE 1 – 5	Cost Driver Categories: HTR Substances		Waste Sources		Productivity	Cost Risk		
		Hazardous / Toxic	Contact, Remote Radiological	Mfg, Bases, & Depot Facilities	Environmental Restoration Sites	Personnel Protection Level	Medic, Liabl, & Regulatory Risk	Technology, & Scope Risk	Cost Ranges, & Unknown Risk
1 Environmental Program Management									
.01 Program Management	0								
.02 Program Support	0								
2 HTR Material Management									
.01 HTR Material Management and Support									
.01 Pollution Prevention Program Implementation	0								
.02 Compliance Program Implementation	0								
.02 HTR Material Control and Distribution									
.01 Requisition/Acquisition	0								
.02 Handling/Distribution	0								
.03 Management/Control of Use	0								
.04 Recovery	0								
.05 Reuse	0								
.06 Recycle	0								
.03 HTR Material Management Facilities									
.01 Personnel Protection	0								
.02 HTR Capital Facilities/Equipment	0								

CBS Depth Score

0 ==> Cost tool does not address this CBS element.
1 ==> Cost tool addresses less than 10% of subordinate CBS elements.
2 ==> Cost tool addresses from 10% to 24% of subordinate CBS elements.
3 ==> Cost tool addresses from 25% to 49% of subordinate CBS elements.
4 ==> Cost tool addresses from 50% to 74% of subordinate CBS elements.
5 ==> Cost tool addresses more than 75% of subordinate CBS elements.

CDC Application

==> No box indicates the CDC cell is not applicable.
==> Cost tool does not address this CDC cell.
////////// ==> Cost tool provides moderate coverage of this CDC cell.
\\\\\\\\\\ ==> Cost tool provides significant coverage of this CDC cell.

FIGURE 7-5.—RACER-ENVEST Matrix: Application to CBS Elements 1 and 2 and CDC

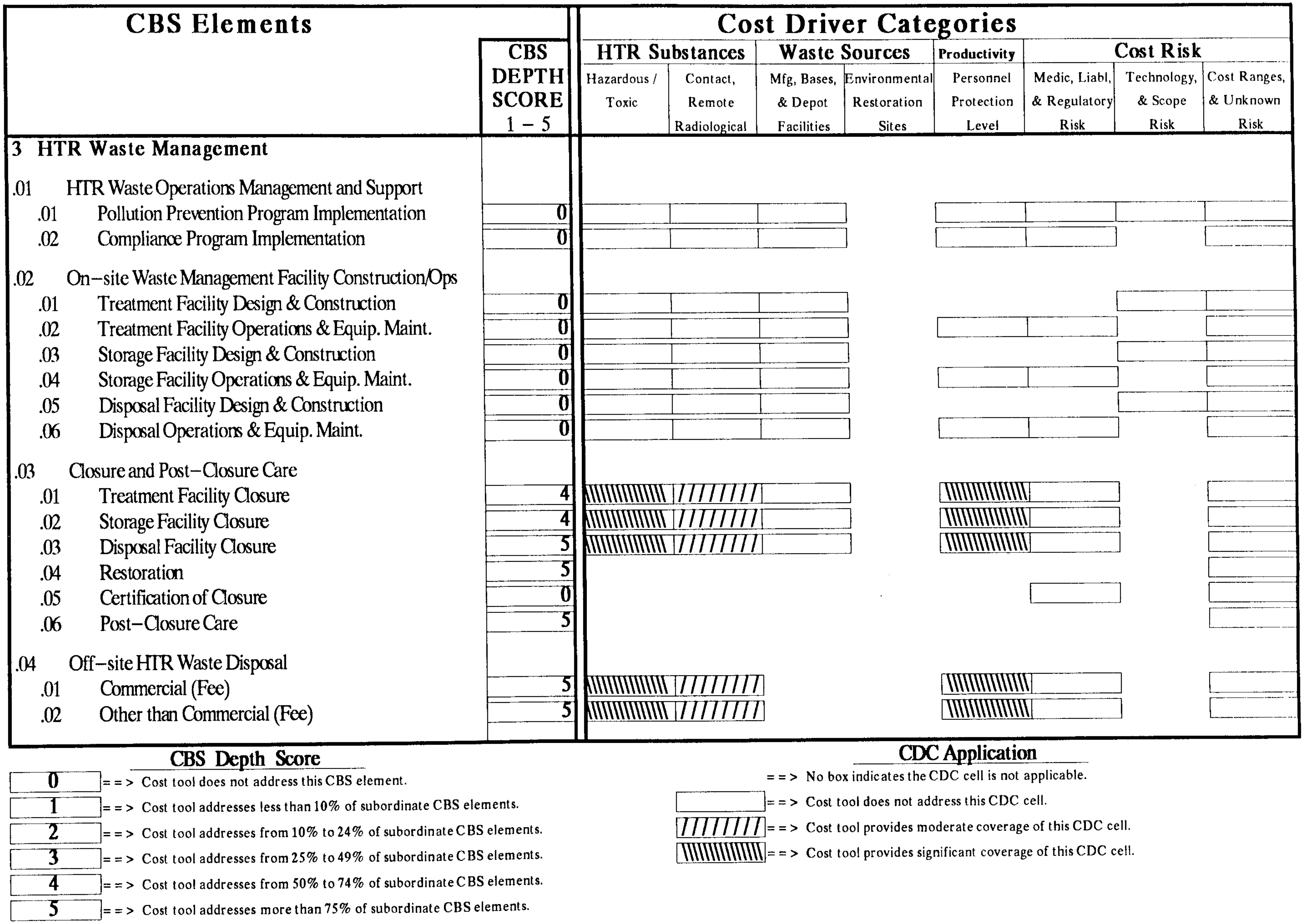

FIGURE 7-6.—RACER-ENVEST Matrix: Application to CBS Element 3 and CDC

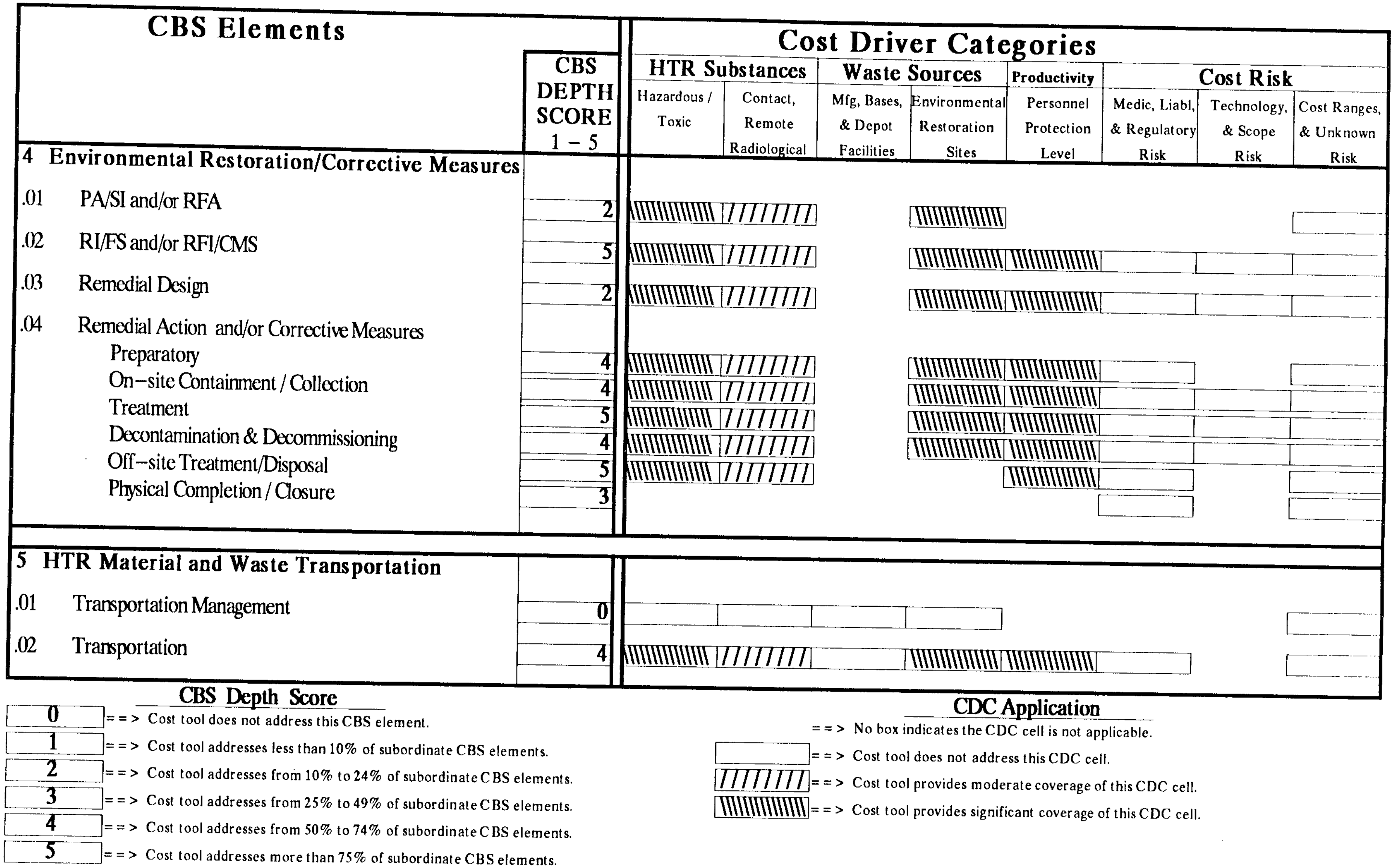

FIGURE 7-7.—RACER-ENVEST Matrix: Application to CBS/CDC

LCC estimates. RACER-ENVEST and MCACES may be applicable to estimating CBS 3.02 On-Site Waste Management Facility Construction/Operations, but the estimator must exercise caution. The complexity of design for an incinerator used as part of an on-going waste-stream treatment is greater than the design for incinerators most typically used for ER. The suitability of these ER cost models to EM operations incinerators must be further investigated.

Figure 7-7 shows that RACER-ENVEST essentially covers all CBS 4.0 elements. The only notable weakness is that it does not address CDC D.0 Cost Risk. RACER-ENVEST provides a place for the user to input a contingency factor but does not provide assistance in developing that factor. Also, because RACER-ENVEST was developed to address typical Air Force cleanup projects, there was never a requirement for the model to address radioactive substances.

7.3.11 Evaluation Test Run

To test the comparative abilities of RACER-ENVEST and MCACES, the estimates they generated for the Gurley Oil Pits project was compared to the data on that project contained in the HCAS database. The Gurley Oil Pits project is typical of ER projects and includes a sufficient number of technologies to compare the estimating capabilities of these models. Figure 7-8 presents the results of this comparative estimating exercise. The RACER-ENVEST estimate was developed by the Project Team; the MCACES estimate used was one developed by Project Time and Cost, Inc. for training purposes.

As shown in figure 7-8, the total direct cost as reported in HCAS and as estimated by MCACES are nearly identical. This result was expected because the MCACES estimate was generated using the actual costs expended on the Gurley Oil Pits project. That is, the individuals generating the estimate went back to original cost documentation and disaggregated it to a much finer degree than shown in the HCAS database. The MCACES estimate, therefore, was very detailed and, in some ways, more representative than the historical cost reported in HCAS. In fact, the differences between the HCAS and MCACES figures are generally due to differences in the assignment of the cost items to the ICEG WBS. The HCAS cost records were not sufficiently detailed to accurately disaggregate the costs into the proper WBS elements. This problem should be alleviated when actual cost data begin to be reported according to the ICEG WBS. The difference between the HCAS and MCACES Grand Totals is due to the Mark Up factors. The HCAS Mark-Ups for this project are relatively low; for training purposes, the MCACES estimate was based on more typical (i.e., higher) Mark Up factors.

The RACER-ENVEST estimates were based solely on the parametric information (e.g., cubic yards of sludge, landfill dimensions) and project contract information available. Very few of the required parameters were available from the HCAS database. Therefore, the Project Team used the design schematics provided by the USACE. The Project Team consulted with the Air Force Civil Engineering Services Agency, which was responsible for the development of the RACER-ENVEST model, to develop this estimate.

TABLE 7-6.—RACER-ENVEST and MCACES Estimates Compared to HCAS Cost Data on the Gurley Oil Pits Project

GURLEY OIL PIT PROJECT	HCAS FY 1993 $	RACER-ENVEST FY 1993 $	MCACES FY 1993 $
4.4 HTRW Remedial Action			
Preparatory			
4.04.01 Mobilization and Preparatory Work	0	0	86,182
4.04.02 Monitoring, Sampling, Testing	22,968	334,941	552,145
4.04.03 Site Work	163,165	199,673*	162,504
Total Preparatory	**186,133**	**534,614**	**800,831**
On-Site Containment/Collection			
4.04.05 Surface Water Collection and Control	45,084	45,084*	36,415
4.04.08 Solids Collection and Containment (Landfill)	906,341	912,877	751,839
4.04.09 Liquids/Sediments/Sludges Collection and Containment	55,584	55,385	57,622
Total On-Site Containment/Collection	**1,007,009**	**1,013,346**	**845,876**
Treatment			
4.04.13 Physical Treatment	1,038,214	157,013	861,650
4.04.15 Stabilization/Fixation/Encapsulation	1,813,621	1,105,502	1,455,493
Total Treatment	**2,851,835**	**1,262,515**	**2,317,143**
Disposal			
4.04.19 Disposal (Commercial)	1,406	4,563	11,750
Total Disposal	**1,406**	**4,563**	**11,750**
Physical Completion/Closure			
4.04.20 Site Restoration	194,762	123,352	208,944
4.04.21 Demobilization	0	0	22,616
Total Physical Completion/Closure	**194,762**	**123,352**	**231,560**
Total Direct 4.4 HTRW Remedial Action	*4,241,145*	*2,938,390*	*4,207,160*
Total Mark-up (Indirect, Fee, Project Management)	*1,781,281*	*2,503,150*	*2,804,652*
Grand Total Gurley Oil Pit Construction and Operation (Not Including Remedial Design)	***6,022,426***	***5,441,540***	***7,011,812***

*To develop the RACER-ENVEST estimate, historical costs contained in HCAS ($20,132 for monitoring well demolition under CBS 4.04.03 and $45,084 for erosion control under CBS 4.04.05) were entered for the required "user-defined" estimates.

Because of the condition of the historical data reported in HCAS, the RACER-ENVEST estimate is better compared to the MCACES estimate. The only cost element showing a significant difference is CBS 4.04.13 Physical Treatment. The physical treatment in question is coagulation/flocculation of 7,000,000 gallons of waste water. The actual treatment facility design and operational requirements were apparently much more elaborate than that which was assumed by the RACER-ENVEST model. Due to limited information available, this difference could not be reconciled.

The Project Team explains the differences between the RACER-ENVEST and MCACES estimates as follows:

- Preparatory

  - RACER-ENVEST does not have a cost model for mobilization; mobilization is assumed to be included in the other models (e.g., excavation includes mobilization of excavation equipment). This convention is not consistent with the ICEG WBS.

  - RACER-ENVEST's estimate for sampling and analysis is lower than the MCACES estimate. Again, RACER-ENVEST allows design (in this case quantity and type of sampling) to be edited, but the Project Team did not edit any default information.

  - Both mobilization and most of the sampling analysis cost in HCAS are included in other CBS elements.

- On-Site Containment/Collection

  RACER-ENVEST estimated these elements remarkably well. This is not a coincidence. The capping model provides more analytical flexibility than the Treatment models, and the design information available to the Project Team was sufficient to provide accurate input data.

- Treatment

  There is an apparent discrepancy between the design assumed by the RACER-ENVEST model and the design actually employed.

- Disposal

  This is one of the two areas (the other is Mark Ups) where, for training purposes, the MCACES estimate was based on typical costs rather than actual costs. The actual disposal scope was used for the RACER-ENVEST estimate and, therefore, was less than the MCACES estimate.

- Physical Completion/Closure

RACER-ENVEST does not have a model that specifically addresses regrading and backfilling of a pit. Therefore, the Project Team took advantage of the flexibility of the Capping model to estimate similar activities. As evidenced by the result, this "quick fix" procedure may not have been sufficient.

- Mark Ups

  The MCACES estimate for this element was modified for training purposes. The Mark Up reported in HCAS is, apparently, unusually low in this area. The RACER-ENVEST estimate for Mark Up seems to be on the high side because the percentage of increase is greater than MCACES's.

7.3.12 Conclusions/Recommendations

7.3.12.1 HCAS: Conclusions

The HCAS database provides valuable project cost information. It is designed to provide project engineers with enough information to develop rough order of magnitude estimates based on analogy to similar projects. In this regard it is sufficient in design and content.

As is the case with any database, the quality of the HCAS database is a function of the quality of data it contains. The HCAS requirement that data input be checked at data screening centers (see section 7.3.2) will be instrumental in assuring this quality is maintained. The data for the Gurley Oil Pits project were entered into HCAS disaggregated in a manner that did not conform to the ICEG WBS. This problem should not recur because the contributing agencies have agreed to execute projects and report data using the ICEG WBS.

HCAS does not provide sufficient parametric information. Very few of the parameters necessary to generate estimates with RACER-ENVEST were available.

7.3.12.2 RACER-ENVEST: Conclusions

RACER-ENVEST is flexible throughout the design phases of an ER project. Because the model provides a detailed design based on conceptual information, the design can be modified and reestimated as the design definition evolves. Therefore, RACER-ENVEST can be used as a parametric estimating tool as well as a unit-cost model. A caution to the user, however, is in order here.

RACER-ENVEST, like any other parametric model, requires knowledge and caution on the user's part. Users must have knowledge of the cost model's algorithms and basis to use the model correctly (i.e., within the bounds of its intended use). The user must exercise caution when using the model. As illustrated in the Gurley Oil Pits example, the physical treatment estimate was substantially low because the model's assumed design is significantly different than the actual design.

The user must, therefore, be familiar with both the model's algorithm and the assumed design to be estimated. In particular, RACER-ENVEST is based on the reverse engineering

of a single project type; therefore, a change in parameters results in a change in output that is dependent on the model's algorithms. These algorithms are based on the developers' engineering judgment and assumptions regarding how changes in parameters affect changes in design and, consequently, the estimate. This is reflected by the evaluation test run example (section 7.3.11).

7.3.12.3 MCACES: Conclusions

MCACES estimates are defensible, correlated to design, generally well documented, very comprehensive, and based on a significant amount of data. They are particularly suited to estimating conventional construction and environmental clean-up projects.

MCACES estimates need a design at least a 30% complete and require the input and/or selection of many detailed line items. The user must be a professional cost engineer and experienced with MCACES. The estimates are subject to the experience and judgment of the estimator.

7.3.12.4 HCAS, RACER-ENVEST, and MCACES: Recommendations

These models and databases are complementary in estimating capability. We recommend that the link between them be completed. It is our understanding that the Naval Facilities Engineering Command, in concert with a Tri-Services Committee (Air Force, Army, and Navy) is developing a "true" Windows version of RACER-ENVEST. This version will include object linking and embedding and will allow free data flow interchange between RACER-ENVEST and MCACES, which is also being converted to a true Windows environment by the USACE. We recommend that HCAS also be converted or reprogrammed into the true Windows environment to complete the data exchange capability.

The HCAS database should be updated to include fields to record the parameters associated with a technology. The required parameters included for each of the technologies addressed by RACER-ENVEST will provide a good starting point. For example, the current version of HCAS offers the user only the cost per groundwater well (i.e., $X each) as a parameter. We recommend that the required parameters of the model be included in the HCAS database. For groundwater wells, the required parameters are:

- Depth to groundwater
- Depth to base of contamination
- Formation (unconsolidated/consolidated)
- Flow rate per well
- Project duration
- Safety level (personnel protection level A–E).

We believe these parameters are essential in understanding the CERs of these systems.

We recommend that the application of these systems for estimating CBS 3.03 Closure and Post-Closure Care be validated. The ER technologies included in HCAS, MCACES, and RACER-ENVEST have direct application to many RCRA closure activities. In chapter 6, we recommend that further research be conducted in this area. These models also should be further evaluated to determine their application for estimating CBS 3.02 HTR Waste Management activities.

8 EVALUATION OF COST-ESTIMATING REPORTS

This section describes the results of an evaluation of engineering case studies, scientific articles, cost compendia, and reports with respect to their relevance and utility as tools to estimate EM costs.

On the basis of the evaluation, each document was placed in one of three classes defined according to the following criteria:

- *Class I* documents are applicable to the Short-Term Plan and clearly merit further investigation of their utility and application as cost-estimating tools.

- *Class II* documents contain either a modest amount of cost information that can be related to the CBS or indicate that additional information may be available. Nine of the documents listed in the bibliography address remediation activities, while the remaining three documents concern themselves predominantly with EM.

- *Class III* documents clearly have little or no direct application as EM cost-estimating tools.

Abstracts of Class I and Class II documents are in sections 8.2 and 8.3. Abstracts of Class III documents are not contained in this report because the reports are of little or no value for estimating EM costs for MDAPS.

8.1 BIBLIOGRAPHY OF DOCUMENTS EVALUATED

This section provides citations for all documents evaluated. Class I and Class II documents are listed by the CBS element each addresses.

8.1.1 Class I Documents

Full citations for Class I documents are provided in section 8.2.1 and appendix C.

CBS 2.0

Mooney, J.A., and L.A. Hermansen. *Hazardous Material Life-Cycle Cost Model Systems User/Operators Guide.*

Hermansen, L.A., et al. *Hazardous Material Life-Cycle Cost Model Systems Managers Guide.*

Ly, H.L., and D.M. Pearsall. *Hazardous Material Life-Cycle Cost Model Technical Manual Version 1.0.*

CBS 3.0

Roberts, R.M., et al. *Hazardous Waste Minimization Initiation Decision Report.*

Feizollahi, Fred, and David Shropshire. *Interim Report: Waste Management Facilities Cost Information for Hazardous Waste.*

CBS 3.03

Sinski, Patricia M., Robert Martin, and J.R. Finney. *Evaluating Cost Estimates for Closure and Post-Closure Care of RCRA Hazardous Waste Management Units.*

CBS 3.04, 4.04.04

Kim, B.J. *An Analysis of Army Hazardous Waste Disposal Cost Data.*

CBS 3.04

Kuryk, B.A. *Economic Analysis of the Recovery and Reuse of Explosives.*

8.1.2 Class II Documents

Full citations for Class II documents are provided in section 8.2.2 and appendix C.

CBS 2.0 and 3.0

Comptroller General. *Nuclear-Powered Ships: Accounting for Shipyard Costs and Nuclear Waste Disposal Plans.*

Kirsch, F.W., and G.P. Looby. *Waste Minimization Assessment Centers - Cost Savings Recommended and Implemented in Twelve Manufacturing Plants.*

Mount, J.F., et al. *Economic Analysis of Hazardous Waste Minimization Alternatives.*

CBS 3.0

U.S Department of Energy. *Preliminary Estimates of the Total-System Cost for the Restructured Program: An Addendum to the May 1989 Analysis of the Total-System Life Cycle Cost for the Civilian Radioactive Waste Management Program.*

CBS 4.0

Burgher, Brian, Mike Culpepper, and Werner Zieger. *Remedial Action Costing Procedures Manual.*

Castro, J.M. *Cost Estimating Relationships for Environmental Cleanup Projects at U.S. DOE Facilities.*

Counce, R.M., J.H. Wilson and C.O. Thomas. *Manual for Estimating Cost of VOC Removal from Groundwater.*

Diggs, I.W., and R.F. Gimpel. *MAWS—A Development Program and Demonstration to Reduce Vitrification Remediation Treatment Costs.*

Metzer, Nancy, Michael Corbin, and Scott Cullinan. *In-Situ Volitization (ISV) Remedial System Cost Analysis.*

Piskin, Kemal, and Bernard A. Donahue. *Method for Calculating Costs of Underground Storage Tank Closure at Fort Dix, New Jersey.*

Tonn, Bruce, et al. *Costs of RCRA Corrective Action, Interim Report.*

U.S Department of Energy. *INEL Cost Estimating Guide, Volume II, Environmental Restoration.*

Yang, Edward C., et al. *Compendium of Costs of Remedial Technology at Hazardous Waste Sites.*

Youngblood, A., and C. Ulibarri. *A Compendium of Cost Data For Environmental Restoration Technologies, Methods, and Processes.*

CBS 4.0 and 5.0

Schlueter, R., and J.J. Schafer. *Low-Level and Transuranic Waste Transportation, Disposal and Facility Decommissioning Cost Sensitivity Analysis.*

8.1.3 Class III Documents

Full citations for Class III documents are provided in appendix C.

Comptroller General. *DoD Environment Cleanup; Information on Contractor Cleanup.*

Economic and Environmental Considerations for Incremental Cost Analysis in Mitigation Planning.

Graves, M.J., and D. Saul. *Decommissioning Waste: Less Volume, Less Cost.*

Kim, B.J. *Validation of the U.S. Army's Current Hazardous Waste Data.*

Kwist, Thomas A. *Remediation Versus Prevention of PCB Contamination: A Comparison Based on Risk and Cost Analysis.*

Pratapagiri, Gopal. *Computer Program for Estimating Decommissioning Costs of Nuclear Power Plants.*

Rivera, A.L., et al. *Challenges in the Development of Integrated Cost Models to Address the Economic Aspects of Waste Confinement Systems.*

Wisenbaker, W., G. Turi, and R. Shangraw. *Lessons Learned and New Initiatives in Cost and Schedule Estimating.*

8.2 ABSTRACTS OF CLASS I REPORTS

This section contains abstracts of Class I reports in order of the CBS. Abstracts are presented in the order in which they are listed in section 8.1.1.

8.2.1 *Hazardous Material Life-Cycle Cost Model Systems User/Operators Guide*

Mooney, J.A., and L.A. Hermansen. *Hazardous Material Life-Cycle Cost Model Systems User/Operators Guide,* Naval Medical Research and Development Command, Naval Health Research Center, Report No. 92-18, September 1992, AD-A259154.

This report is a system description and instruction manual for the computer program Hazardous Material Life-Cycle Cost Model. The program allows the estimation of total LCC incurred when using a variety of hazardous materials in the construction, maintenance, and repair of U.S. Navy systems and facilities.

The computer program allows the inclusion of the following cost factors in the development of a LCC estimate:

- Claims and Compensation
- Disposal
- Engineering Controls
- Fines and Penalties
- Medical Surveillance
- Medical Treatment
- Permits and Certification
- Personal Protective Equipment
- Procurement
- Spill Contamination
- Storage
- Training
- Workplace Monitoring.

No specific hazardous materials are identified, nor does the report provide any cost data or additional breakdown for the above cost factors.

Because of the lack of any specific information in the report, no evaluation of the relationship of the tool to the CBS and CDC can be given.

8.2.2 *Hazardous Material Life-Cycle Cost Model Systems Managers Guide*

Hermansen, L.A., J.A. Mooney, and W. Pugh. *Hazardous Material Life-Cycle Cost Model Systems Managers Guide,* Naval Medical Research and Development Command, Naval Health Research Center, Report No. 92-17, September 1992, AD-A259156.

This is an instruction manual for a computer-based mathematical model that allows the computation of certain LCCs associated with the use of hazardous materials in the construction, maintenance, and repair of U.S. Navy systems and facilities. The model estimates only the LCCs incurred in assuring the health and safety of workplace personnel and the protection of the environment.

The model requires the user to specify values for a number of parameters including the type of material, phase of the life cycle, process, exposure type, and costs. The latter are given in a three-level hierarchical arrangement of cost item, cost element, and cost factor. One or more cost items are combined into a cost element, and one or more cost elements are combined into a cost factor. From the specification of these parameters total LCCs are determined by a mathematical formula presented in the manual.

The manual provides no indication of actual costs of any of the contributing factors. However, appendix C indicates a number of sources from which these costs may be obtained.

Due to the lack of any information on specific materials, processes, levels of protection, and costs in the report, no evaluation of the relationship of the tool to the CBS and CDC is given.

8.2.3 *Hazardous Material Life Cycle Cost Model Technical Manual (Version 1.0)*

Ly, H.L., and D.M. Pearsall. *Hazardous Material Life Cycle Cost Model Technical Manual Version 1.0,* Naval Medical Research and Development Command, Naval Health Research Center, Report No. 92-19, September 1992, AD-A259208.

This manual contains information on the Hazardous Material Life-Cycle Cost Model computer program. The manual describes the program's data elements, structure, and source code.

The program's function is to allow the computation of the total LCC of a wide range of hazardous materials.

The materials are characterized by their chemical or physical properties, their limits on exposure, associated occupational health hazards, treatment options, and required personal protective equipment. The program also contains a description of its life-cycle phases of each material.

The data elements are in 12 databases. These databases include a file of hazardous materials, a life-cycle table for each hazardous material, and a cost-factor table for each aspect of the material's life-cycle. The information in these databases can be used to calculate LCCs.

The program's subroutines are in a tree that shows the order in which each subroutine is used in the life-cycle computation process. There are 25 procedures in the computation. The program computes an estimated LCC and a variance of the cost for a given scenario for each material's life cycle.

Due to the lack of any explanatory or tutorial material in the manual, no evaluation of the relationship of the tool to the CBS and CDC can be given.

8.2.4 *Hazardous Waste Minimization Initiation Decision Report*

Roberts, R. M., J.L. Koff, and L.A. Karr. *Hazardous Waste Minimization Initiation Decision Report,* Naval Civil Engineering Research Laboratory, TN-1787, June 1988, Volume 1 (AD-A199221), Volume 2 (AD-A199222).

This two-volume report provides a wealth of information on the U.S. Navy's generation, management, and remediation of hazardous waste and their associated costs.

Volume I contains a summary of the processes that generate hazardous waste, the volume of such waste, and the current and emerging technologies that can be applied toward its management and treatment. The following waste-generation processes are considered:

- Industrial Waste-Water Treatment Plant Operations
- Electroplating and Circuit Board Manufacture
- Ordnance Operations
- Bilge Emptying and Cleaning Wastes
- Abrasive Blasting
- Painting Operations
- Munitions Demilitarization Operations
- Piping Flushing and Cleaning
- Boiler Lay-up
- Boiler Cleaning
- Fluids Change-out
- Battery Repair and Replacement
- Cleaning With Solvents
- Bilge and Ship Tank Derusting
- Metal Preparation

- Chemical Paint Stripping
- Torpedo Cleaning.

Cost information is provided for the treatment of a number of hazardous wastes generated by these processes including wastewater, sludge, solvents, and waste from electroplating/metal finishing, abrasive blasting and painting operations, battery repair and replacement, metal preparation, and paint stripping. Only total estimated costs are given, and all costs are related to specific Navy installations.

Also included in Volume I are estimates of the resources required to meet the Navy's near-term goal of minimizing the amount of hazardous waste generated at its facilities.

Volume II consists of 13 appendices containing a wide variety of related information.

Appendix A consists of technology assessment data sheets for 23 Navy installations. The data sheets contain information on total costs incurred in the treatment of wastes generated by a variety of processes and types and volumes of hazardous materials generated at these facilities.

Appendix B contains a flow diagram of eight of the Navy's industrial waste-water treatment plants.

Appendices C, D, and E provide detailed descriptions of the physical/chemical, incineration and thermal destruction, and biological treatment processes employed by the Navy.

Appendix F describes the results of a study on the biotreatability of "pink water," a wastewater stream generated in munitions plants, and provides capital and operating costs for plants of various capacities.

Appendix G describes the results of feasibility tests, including the economic considerations, on the reclamation of used blast grit from Navy shipyards.

Appendix H is a report on the feasibility of using supercritical fluids for the minimization of Navy hazardous waste. This report also includes estimates of capital and operating costs for several minimization strategies.

Appendix I discusses several stabilization/solidification processes.

Appendix J contains a description of a process for the detoxification of wastewater through the use of immobilized microorganisms. It also includes estimates of capital and operating costs for a pilot-scale process.

Appendix K describes a computer program designed to assess the cost-effectiveness of specific waste minimization technologies. It presents parameters and equations from which costs can be estimated.

Appendix L contains the results of a study to determine the order of preference of a large number of hazardous-waste treatment alternatives.

Appendix M contains 26 proposals for the development of technology to minimize the volume of hazardous waste generated by Navy industrial operations.

8.2.5 *Interim Report: Waste Management Facilities Cost Information for Hazardous Waste*

> Feizollahi, Fred, and David Shropshire. *Interim Report: Waste Management Facilities Cost Information for Hazardous Waste,* developed for the U.S. Department of Energy Idaho National Engineering Laboratory by EG&G Idaho, Inc., EGG-WM-11432, August 1994. [No secondary source identified.] Point of contact: David Shropshire, (208)526-6800.

This report, which primarily addresses CBS 3.0, presents a method for estimating the costs of treatment, storage and disposal facilities required to manage the DOE's hazardous waste streams. For purposes of estimating these costs, treatment, storage, and disposal processes are divided into distinct modules that can be assembled into different types of treatment, storage, and disposal facilities. The modules are:

- Treatment front end support
- Receiving and inspection
- Assay, sort and packaging
- Aqueous waste treatment
- Incineration
- Organic removal
- Recycling
- Deactivation
- Mercury separation
- Grout stabilization
- Certification and shipping
- Shallow land disposal.

For each module, the report provides a set of curves that show estimates of the costs of facility construction, pre-operation, Operating and Maintenance, D&D, and total LCC—all as a function of the facility's input capacity. The estimates are given in three formats:

- Required manpower in full-time equivalent workers
- Total cost in dollars
- Cost per unit in dollars (total LCC only).

All cost estimates are expressed in 1994 dollars and do not consider the time value of money.

8.2.6 *Evaluating Cost Estimates for Closure and Post-Closure Care of RCRA Hazardous Waste Management Units*

Sinski, Patricia M., Robert Martin, and J.R. Finney. *Evaluating Cost Estimates for Closure and Post-Closure Care of RCRA Hazardous Waste Management Units,* developed for the U.S. Environmental Protection Agency Region IV, Atlanta, Georgia,by PRC Environmental Management, Inc., Work Assignment No. R04049, May 13, 1994. [No secondary source identified.]

This report, which primarily addresses CBS 3.03, consists of a manual that offers a method by which EPA and State RCRA permit writers may evaluate the accuracy of cost estimates for closure and post-closure care of RCRA treatment, storage, and disposal units prepared by the owners of these units. The method focuses on cost estimating for specific closure activities associated with common types of treatment, storage, and disposal units.

The manual contains over 100 cost-estimating worksheets divided into 9 categories of unit-specific worksheets and 6 categories of support worksheets. The worksheets for a particular unit divide the total closure activity for that unit into a number of specific tasks. The worksheets also contain unit cost data for some of these tasks. The worksheets are the primary means by which the accuracy of cost estimates prepared by owners or operators is evaluated.

Ten specific hazardous-waste management units are considered:

- Container storage areas
- Tank systems
- Surface impoundments
- Waste piles
- Land treatment
- Landfills
- Incinerators
- Subpart X units
- Drip pads
- Containment buildings.

The manual includes a discussion of the relevant closure requirements and the activities that an owner or operator will undertake during closure for each type of hazardous-waste management unit. The manual also provides example sequences of closure activities in the form of flow charts, the cost-estimating worksheets appropriate to that unit, and instructions on their use.

The manual also provides a description of a number of generic closure activities, including:

- Decontamination
- Sampling and analysis

- Installation of wells
- Transportation of hazardous waste
- Treatment and disposal of hazardous waste.

The manual contains worksheets for estimating the associated costs and unit cost tables for some of the component tasks for each of these activities.

The last chapter of the manual discusses post-closure care and provides worksheets for estimating the corresponding costs.

Information on costs incurred for personal protective equipment that may be required during unit closure is contained in an appendix.

8.2.7 *An Analysis of Army Hazardous Waste Disposal Cost Data*

> Kim, B.J., et al. *An Analysis of Army Hazardous Waste Disposal Cost Data,* developed for the U.S. Army Corps of Engineers, Construction Research Laboratory, USA CERL-TR-N-91/17, April 1991, AD-A236654.

This report primarily addresses CBS 3.04 and 4.04.04. It provides information on unit costs and total costs incurred in the disposal of many types of Army hazardous waste. The cost data were obtained from the DRMS, which in turn derived the information from existing hazardous waste disposal contracts. The data include costs incurred in the disposal of all Army-generated hazardous waste in the Continental United States during FY 1988.

The information provided by DRMS is given by CLINs that specify several thousand types of hazardous waste materials, ranging from solvents to batteries, sludges, oils, and paint-stripping waste. Each CLIN is classified according to type of waste, amount of waste, and container. Descriptive titles for most CLINS are given in the report.

The report provides maximum, minimum, and average unit costs for each CLIN and the total FY 1988 disposal cost for the top 20 CLINs. It also contains contract dollar values for all waste disposal contracts active during FY 1988.

Part of the report is an analysis of the cost data that identifies the CLINs with the highest unit and total disposal costs and the CLINs with the highest difference between maximum and minimum disposal costs. The report also includes an analysis of the variation in disposal cost and its dependence on factors such as quantity and type of waste; transport distance; material phase; container size and condition; local, State, and Federal regulations; manner of packaging; and level of concentration.

8.2.8 *Economic Analysis of the Recovery and Reuse of Explosives*

> Kuryk, B.A. *Economic Analysis of the Recovery and Reuse of Explosives from Obsolete and Unserviceable Conventional Ammunition,*

developed for the U.S. Army Toxic and Hazardous Materials Agency by Arthur D. Little, Inc. ADI/REF-54144-03, May 31, 1986, AD-A170445.

This report primarily addresses CBS 3.04 and is a study of the costs associated with the disposal or recovery of obsolete and unserviceable conventional ammunition. The ammunition is divided into five representative categories:

- 90-mm cartridges filled with TNT or Composition B
- 3.5-inch rockets filled with Composition B
- 5-inch rocket warheads filled with TNT or Composition B
- MK-9 depth charges filled with TNT
- M59-Al semi-armor-piercing bomb filled with TNT.

Three disposal options and two recovery options were selected for economic analysis:

- Disposal Options
  - Thermal treatment through open-field detonation
  - Removal of explosives from the munitions hardware by the hot water washout/steamout process followed by incineration of all energetic components and thermal treatment of the metallic hardware
  - Removal of explosives from the munitions hardware by the meltout process followed by incineration of all energetic components and thermal treatment of the metallic hardware
- Recovery Options
  - Removal of explosives from the munitions hardware through the hot water washout/steamout process followed by the refining of the recovered explosives and thermal treatment of the metallic hardware
  - Removal of explosives by the meltout process followed by the refining of the recovered explosives and thermal treatment of the metallic hardware

The report includes a database for generic capital and operating costs for the disposal or recovery of the resource. These costs are applied in a case study designed to determine the comparative costs of the five options. The case study shows that thermal treatment through open field detonation is the most cost-effective option, enjoying significant capital and operating cost advantages over the other options.

8.3 ABSTRACTS OF CLASS II REPORTS

This section includes abstracts of Class II reports. Abstracts are presented in the order in which they are listed in section 8.1.2.

8.3.1 *Nuclear-Powered Ships: Accounting for Shipyard Costs and Nuclear Waste Disposal Plans*

Comptroller General. *Nuclear-Powered Ships: Accounting for Shipyard Costs and Nuclear Waste Disposal Plans,* developed for the Subcommittees on Defense, Senate and House Committees on Appropriations by the U.S. General Accounting Office (Washington, DC), Report No. NSIAD-92-256, July 1992, AD-A253452.

This is a report on the costs of disposal and recycling of low-level nuclear waste associated with the inactivation or overhaul of nuclear-powered and nonnuclear submarines and cruisers. It provides the total costs incurred during FY 1991 at the Puget Sound Naval Shipyard in work conducted on 24 nuclear-powered and 3 nonnuclear-powered vessels.

The total cost is differentiated between nuclear-powered and nonnuclear-powered vessels and is further broken down into charges for labor, materials, and overhead.

The report also provides cost evaluations and projections for the handling and disposal of all nuclear materials and radioactively contaminated materials of nuclear-powered vessels. Actual costs are given for FY 1991, while projections are offered for the next 20 years. The following materials are considered:

- Low-level radioactive waste
- Mixed low-level radioactive and chemically hazardous waste
- Naval reactor fuel
- Defueled reactor compartments
- Lead shielding and containers.

Total cost per year and cost per cubic foot of material are provided and are broken down into costs of transportation and burial at commercial or DOE sites and for shipyard processing and preparation. Only annual shipping costs to a storage facility are given for naval reactor fuel.

8.3.2 *Waste Minimization Assessment Centers—Cost Savings Recommended and Implemented in Twelve Manufacturing Plants*

Kirsch, F.W., and G.P. Looby. *Waste Minimization Assessment Centers—Cost Savings Recommended and Implemented in Twelve Manufacturing Plants,* developed for the Risk Reduction Engineering Laboratory of the U.S. Environmental Protection Agency by Industrial

Technology and Energy Management, University City Science Center (Philadelphia, Pennsylvania), Report No. CONF-9104243, April 1991. DOE-RAPIC No. 9918.

This document reports the results of a study designed to aid small- and medium-size manufacturers reduce or eliminate waste during the manufacturing process. As part of a pilot project sponsored by University City Science Center (Philadelphia, Pennsylvania), teams of scientists and students from two universities carried out assessment programs at 12 manufacturing sites to obtain information on waste generation and manufacturing operations. From this information, the teams developed detailed recommendations for waste minimization and calculated their cost-effectiveness. The teams also obtained follow-up information on the implementation of their recommendations and the cost savings actually realized.

The report provides summary information on the actual net cost savings per year for all plants, for each of five categories of waste-minimization opportunities:

- Substitution of plant operation or material
- Changes in technique or control method
- Reduction of solvent use
- Reduction in liquid volume
- Reduction of treatment of sludge.

The financial models underlying these computations take into account the capitalization of costs, depreciation of investments over 5 years, amortization of borrowed capital over 5 years, tax on savings, and a linear increase in implementation costs with time.

The report provides a detailed breakdown of the waste-management costs and net savings for all plants by product category. It also includes information on the amount of savings for each of the five waste-minimization categories for each of the 12 manufacturers.

8.3.3 *Economic Analysis of Hazardous Waste Minimization Alternatives*

Mount, J.B., et al. *Economic Analysis of Hazardous Waste Minimization Alternatives,* developed for the U.S. Army Corps of Engineers by the U.S. Army Construction Engineering Research Laboratories (Champaign, Illinois), Report No. TR-EN-92/05, August 1992, AD-A256989.

This report develops an analytical model for determining the LCCs for various hazardous-waste minimization technologies. It offers a detailed discussion of the various factors determining LCCs and specifies a number of relevant economic terms such as recurring and nonrecurring costs and operating costs. It also gives a mathematical exposition of such factors as simple and compound interest, present value, cost/benefit ratio, savings-to-investment ratio, and discounted payback period.

The main part of the document describes a computer model that allows an analysis of the cost-effectiveness of various hazardous waste-minimization alternatives. For a particular waste minimization technology and waste stream, the model computes the costs associated with the purchase of equipment, facility construction, acquisition of property, materials and supplies, labor, and administration. From these component costs, the model determines the required investment as well as operations and maintenance costs.

The report also contains an analysis of the relative costs of cleaning and degreasing operations when these operations are carried out either in one location or are distributed over several locations. For this analysis, a detailed accounting of equipment and installation costs, operator labor rates, and annual operator labor costs is provided.

Finally the report includes an annotated review of the literature pertinent to the subject and an extensive bibliography.

8.3.4 *Preliminary Estimates of the Total-System Cost for the Restructured Program: An Addendum to the May 1989 Analysis of the Total-System Life Cycle Cost for the Civilian Radioactive Waste Management Program*

U.S. Department of Energy. *Preliminary Estimates of the Total-System Cost for the Restructured Program: An Addendum to the May 1989 Analysis of the Total-System Life Cycle Cost for the Civilian Radioactive Waste Management Program.* Available from: U.S. Department of Energy, Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN. 37831.

This document is an addendum to a previous report that contains estimates of the total-system LCC of the DOE's Civilian Radioactive Waste Management program. This program is intended to accept and manage radioactive waste obtained from civilian and military sources. The waste-management system consists of a repository at Yucca Mountain, Nevada, a monitored retrievable storage (MRS) facility, and a transportation system.

This report is included as a Class II document because it includes the portion of the total-system LCC incurred by defense sectors for the years 1983–2094.

The primary objective of the addendum is to update the cost estimates contained in the previous report by taking into consideration the cost impacts of four changes in DOE's plan. These changes involve a priority focus of the scientific investigation program at the Yucca Mountain site on the identification of potentially adverse effects, a delay in the start of the repository operations until 2010, a start of limited waste acceptance in 1998, and the start of full waste acceptance in 2000.

The total-system LCC estimate is divided into five major categories. Within each of these a further cost breakdown is provided. Costs also are also given under the assumption of either one or two repository sites. The individual cost components addressed are:

- Development and evaluation costs for siting, the MRS facility, transportation, system integration, and program management. Also included are fees to the Nuclear Regulatory Commission.
- Transportation costs including capital and operating costs of providing the transportation system from reactors, defense sites, the MRS facility, and the cask maintenance facility.
- Cost of the repositories including engineering and construction, operation, and closure and decommissioning.
- Cost of the MRS facility including construction, operation, and decommissioning.
- Benefit payments for the first and second repositories and the MRS facility including payments to States and affected Indian Tribes.

For each of these categories, the document provides total annual system costs in constant 1988 dollars for the years 1983–2075 for a single-repository system and the years 1983–2094 for the two-repository system. Also included are the portions of the total-system LCC incurred by the civilian and defense sectors for the years 1983–2094.

8.3.5 *Remedial Action Costing Procedures Manual*

Burgher, Brian, Mike Culpepper, and Werner Zieger, *Remedial Action Costing Procedures Manual,* developed for the Hazardous Waste Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45286 by JRB Associates and CH2M Hill, Report No. EPA/600/8-87/049, October 1987, NTIS PB88-113691.

This manual provides procedures for estimating the costs associated with the planning phase of various RAs involving hazardous-waste sites. Also included are:

- The costs associated with developing the initial site plan for RAs. Included are such items as initial site visit, development of an initial remedial measures plan, planning and performing topographic and geophysical surveys, conducting an environmental sampling program, and developing a community relations plan. The report provides estimates of minimum and maximum costs for labor and various expenses to accuracy only within an order of magnitude.
- The costs associated with the remediation of a landfill from which hazardous waste has migrated into an aquifer used as a potable water supply. RA includes construction of a

slurry wall, construction and operation of a groundwater extraction and treatment system, and replacement of drinking-water wells. The total cost is broken down into direct and indirect capital costs and operating and maintenance costs. All remediation costs given are based on vendor estimates and are claimed to be reasonably accurate by the authors.

8.3.6 *Cost Estimating Relationships for Environmental Cleanup Projects at U.S. DOE Facilities*

Castro, J.M. *Cost Estimating Relationships for Environmental Cleanup Projects at U.S. DOE Facilities,* developed for the U.S. Department of Energy by PEI Associates, Inc. (Arlington, Texas), Project No. 3685-19, February 1990, DOE-RAPIC No. 9623.

This document contains extensive cost data for all major phases of various environmental clean-up projects at DOE facilities. In addition, the report provides descriptions of specific processes and facilities involved in the cleanup projects.

Costs are given for the following:

- RI/FS
- Burial
- Water treatment
- Site work, transportation, and personal protection
- Incineration
- Building/equipment decontamination
- Closure/post-closure.

The total cost of RI/FS is divided into scoping, development of a sampling and analysis plan, data management, health and safety planning, community relations, site characterization, treatability investigations, and data analysis and reporting. Costs are provided for labor, sampling and analysis, sample shipping, and the purchase of sampling equipment.

Five methods of burial of contaminated materials are considered: on-site landfill, engineered cap, off-site disposal, stabilization or solidification, and slurry walls. Costs are provided for construction materials, site work, landfill structures, monitoring systems, gas collection and venting, storm-water control, waste treatment, treatment materials, waste placement, testing, and disposal fees.

Seventeen water treatment options are considered: Flow equalization, sedimentation, granular-media filtration, neutralization, precipitation/flocculation/ sedimentation, carbon adsorption, air stripping, steam stripping, release osmosis, ultrafiltration, ion exchange, wet-air oxidation, activated sludge, sequencing batch reactor, powdered activated carbon treatment, rotating biological disc, and trickling filter. For each of these options, the report provides capital costs for equipment such as piping, pumps, motors and aerators and annual operations and maintenance costs.

Site work, transportation, and personal protection costs are given for excavation, transportation, ground-water pumping, personal protection, UST removal, and on-site and off-site inventory, and residual management.

On-site incineration costs are broken down into costs for site development, incinerator equipment, tanks, conveying equipment, scrubbing systems, utilities, operating labor, supervisory labor, and maintenance. Also provided are commercial off-site incineration prices and surcharges.

Twelve methods of building/equipment decontamination are considered: Demolition, dismantling, dusting/vacuuming/wiping, grit blasting, hydroblasting, painting/coating, scarification, steam cleaning, acid etching, bleaching, flaming, and drilling and spalling. For each method, the total cost is divided into several categories such as equipment, materials, personal protection, and waste disposal.

Closure/post-closure activities include removal of temporary roadways, site regrading, placement of topsoil, seeding, installation of monitoring wells, erection of fences and warning signs, air monitoring, periodic inspection, and leachate removal. Total costs for these activities are given for 22 sites.

Individual clean-up projects are characterized in terms of clean-up area, measured in grouped solid waste management units (SWMUs), acres, or square feet.

8.3.7 *Manual for Estimating Cost of VOC Removal from Groundwater*

> Counce, R.M., J.H. Wilson, and C.O. Thomas. *Manual for Estimating Cost of VOC Removal from Groundwater,* developed for the U.S. Air Force Engineering and Services Center, Engineering and Services Laboratory, Tyndall Air Force Base, Florida by Oak Ridge National Laboratory, Martin Marietta Energy Systems, Inc. (Oak Ridge, Tennessee), ESL-TR-90-50, May 1992, AD-A260303.

This manual describes a spreadsheet-based computer model and contains instructions for estimating the cost of remediation of groundwater contaminated by jet fuel including Benzene, TCE, and similar volatile organic compounds (VOCs). Two methods of removing VOC's by air stripping are considered:

- Packed tower with countercurrent gas-liquid contact
- Rotary air stripping with countercurrent gas-liquid contact.

The emissions resulting from the stripped fuel components are either emitted into the atmosphere or are controlled through activated carbon adsorption or catalytic oxidation.

For each of these treatment options, the computer model determines the total processing cost in current-year dollars per 1000 gallons of water processed. Included in this cost are capital investment costs for air strippers and associated equipment, emission control equipment, and

centrifugal contactor as well as direct and indirect annual operating cost for fuel and electricity, charcoal regeneration, maintenance, and labor.

The report provides an analysis of the sensitivity of treatment cost to the flow-rate of ground water, the stripping factor, and the flooding factor. It also contains a lifetime financial analysis of the processing cost per 1000 gallons of water, assuming equipment depreciation over 20 years. These costs are adjusted to constant 1990 dollars by using estimates for average annual rates of inflation and interest.

8.3.8 *MAWS—A Development Program and Demonstration to Reduce Vitrification Remediation Treatment Costs*

Diggs, I.W., and R.F. Gimpel. "MAWS—A Development Program and Demonstration to Reduce Vitrification Remediation Treatment Costs," *Proceedings of the International Topical Meeting on Nuclear and Hazardous Waste Management: Spectrum '92*, developed for the U.S. Department of Energy by Westinghouse Environmental Management Company of Ohio, August, 1992, DOE-RAPIC No. 06290.

The objective of this study is to determine the relative costs of vitrification and solidification of low-level radioactive and mixed waste. Its subject matter relates to the remediation tasks of Operable Unit (OU) 1 at DOE's Fernald Environmental Management Project. OU 1 consists of several waste pits containing approximately 350,000 cubic meters of pit waste and up to 540,000 cubic meters of contaminated soil.

The authors use a comprehensive LCC model that includes the costs associated with RI/FS, design, construction, treatment and disposal of waste, and 100 years of monitoring.

The report provides the total LCC for both vitrification and solidification, divided into the cost of encasing and the cost of burial. The costs are given as unit costs per cubic meter of waste processed and as total cost for amount of waste contained in OU 1. Both estimates are given in terms of present worth and long-term cost (assuming a yearly 5.5% cost escalation).

The principal conclusion of the study is that the LCC of vitrification and solidification are comparable.

8.3.9 *In-Situ Volitization (ISV) Remedial System Cost Analysis*

Metzer, Nancy, Michael Corbin, and Scott Cullinan. *In Situ Volatilization (ISV) Remedial System Cost Analysis,* developed for the U.S. Army Toxic and Hazardous Materials Agency Edgewood Area, Aberdeen Proving Ground, Aberdeen, Maryland, by Roy F. Weston, Inc. (West Chester, Pennsylvania), Report No. AMXTH-TE-CR87123, August 1987, AD-A184447.

This study contains cost information on the remediation by *in situ* volatilization (ISV) of soil contaminated with volatile compounds. The ISV remediation costs are developed for three hypothetical contamination situations:

- Leak from a small tank covering a small geographic area to a depth of 100 feet

- Tank farm leak in which the area of contamination includes several concentrations of contaminant

- Lagoon serving as a disposal area for degreasers and solvents.

Included in the estimates of the remediation costs are the following components:

- Implementation costs of bench-scale testing, pilot testing, design, and permitting
- Capital costs of equipment, materials, and start-up
- Operations costs of labor, emissions monitoring, power, maintenance, and vapor control.

Equipment costs are further broken down into costs for specific pieces of equipment.

For each of the three hypothetical scenarios, the costs are given as total remediation costs, assuming specific treatment durations, and cost per cubic yard of decontaminated soil.

8.3.10 *Method for Calculating Costs of Underground Storage Tank Closure at Fort Dix, New Jersey*

Piskin, Kemal, and Bernard A. Donahue. *Methods for Calculating Costs of Underground Storage Tank Closure at Fort Dix, New Jersey,* developed for the U.S. Army Engineering and Housing Support Center, Fort Belvoir, Virginia, by the U.S. Army Construction Engineering Research Laboratory (Champaign, Illinois) Report No. USACERL-SR-N-91-28, September 1991, AD-A242357.

This report contains information on the costs of closing USTs as part of the Realignment Project at Fort Dix, New Jersey. The report focuses on the closure costs for 13 specific tanks, three of which are inactive.

Three closure alternatives are considered:

- Temporary closure of a tank
- Permanent closure with tank retention
- Permanent closure with tank removal.

The report also provides the costs of replacing an old tank with a new one and of installing a new tank without prior removal of the old tank.

Costs are given for actual closing or installation activities and related management functions. Closing costs include charges for tank emptying, cleaning, capping of fill lines, removal of the tank and associated equipment, tank transport, tank disposal, and backfilling. Costs for the installation of new tanks include tank costs, installation, and monitoring equipment. Management costs cover hydrological site studies, preliminary leak investigations, and testing of tank integrity. Not included are costs for remediation of soil and groundwater.

The report provides upper and lower estimates and average values for all costs for all 13 tanks.

8.3.11 *Costs of RCRA Corrective Action, Interim Report*

> Tonn, Bruce, et al. *Costs of RCRA Corrective Action, Interim Report,* developed for the U.S. Department of Energy by Oak Ridge National Laboratory, Martin Marietta Energy Systems, Inc., Report No. ORNL/TM-11864, August 1991, DOE-RAPIC No. 04236.

This report provides an estimate of the cost of corrective actions required by the RCRA for non-Federal facilities in the United States. To determine these costs, the authors rely on data contained in two databases, and a computer-based remedial-cost estimating model. One of the databases provides information on all hazardous-waste treatment, storage, disposal, and recycling facilities active in the United States in 1987 and on their SWMUs. The other database contains a sample of the hazardous waste generators in the United States. The Cost of Remedial Action (CORA) cost-estimating model provides cost estimates in 1987 dollars for remediating a site using a specific technology. Several levels of required cleanup are considered including a base case used for comparison purposes and more stringent or less stringent levels of cleanup.

For purposes of estimating RA costs, the SWMUs contained in the database were grouped into eight types including landfills, waste piles, surface impoundments, land treatment units, tanks, tank areas, container areas, and satellite accumulation areas. For each type, specific SWMUs were placed into categories based on the technology that could be applied to it. These technologies are soil capping, RCRA capping, incineration, solidification, soil vaporization, soil flushing, and doing nothing. SWMUs were further distinguished by other parameters including size, landfill liner type, permeability of the upper aquifer, level of risk to the population, amount of contaminants, type of hazardous waste, size of any tanks, age, and whether the SWMU is located in a building.

At the highest level, CORA considers two categories of costs—capital costs and operation and maintenance costs. At level 2, capital costs are divided into technology construction costs, site development costs, and indirect costs for each technology; operation and maintenance costs are divided into operation and maintenance costs and insurance costs for each technology. A level-3 breakdown of costs in each of the level 2 categories is also given, and includes as many as 14 types of costs.

For each type and category of SWMU, a large number of cost estimates was obtained, depending on specific assumptions made regarding the SWMU. These data were used to obtain mean and median costs for each SWMU type and SWMU category. Formulas and estimating relationships for these computations are included in the report.

The report contains a number of tables that specify the treatment technology options for each SWMU type. The report also provides definitions of the variables used in the categorization process and the rules for determining the category of a particular SWMU. Finally, the report reproduces a number of text-based computer screens used to input data to the cost-estimating model.

8.3.12 *INEL Cost Estimating Guide: Volume II, Environmental Restoration*

> Management and Operations Contractors of the Idaho National Engineering Laboratory. *INEL Cost Estimating Guide: Volume II, Environmental Restoration,* Idaho National Engineering Laboratory, U.S. Department of Energy, June 1993. [No secondary source identified.]

This document, developed by contractors performing work at the DOE's Idaho National Engineering Laboratory (INEL), is a guide to estimating costs associated with various ER projects conducted at INEL. It offers a set of procedures, a standardized Code of Accounts, a UPB, and labor-rate tables. The report claims that with these data, cost estimators can arrive at "consistent and reliable" estimates for INEL's ER projects.

The guide encompasses four specific aspects of estimating the cost of an ER project:

- RA (divided into assessment and clean-up activities)
- D&D
- Removal of USTs and restoration of the storage tank site
- Program management and support (divided into operations and services).

The guide does not consider costs associated with construction activities, waste management, contingency, or escalation. Nor does the guide consider the costs associated with the operations part of program management and support.

The guide contains forms to be used in cost estimating and a listing of codes of account for RA, D&D, UST removal, and site restoration. The forms are applicable to all types of radioactive and non-radioactive waste. Also included is a UPB that lists average values and ranges of values for hourly labor rates and cost of materials for each of the four components.

8.3.13 *Compendium of Costs of Remedial Technology at Hazardous Waste Sites*

Yang, Edward C., et al. *Compendium of Costs of Remedial Technologies at Hazardous Waste Sites,* developed for the Hazardous Waste Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency by Environmental Law Institute, Washington, DC. Report No. EPA/600/2-87/087, October 1987, NTIS PB 88-113477, DOE-RAPIC No. 06524.

This report contains cost data on the remediation of 31 hazardous-waste sites employing one of the following seven technologies:

- Surface controls
- Ground-water and leachate controls
- Aqueous and solids treatment
- Gas migration control
- Material removal
- Water and sewer line rehabilitation
- Alternative water supply.

For each technology, the report provides a range of total actual unit-remediation costs incurred at a number of sites at which that technology was employed. In most cases,the costs are divided into capital costs and operating costs. In some cases, only the total cost is provided.

Also included in the report are estimated unit-remediation costs derived from generic engineering construction manuals and standard estimation techniques. These estimates are based on tables of component costs that include such cost items as materials, capital costs, construction, excavation, transportation, disposal, and operation and maintenance. All costs are given in constant 1982 dollars.

For each technology, the report also contains a list of some of the major factors that influence actual or estimated remediation costs and that are responsible for the divergence between actual and estimated costs.

All costs given in the report relate to actual sites. However, in most cases no information regarding the nature of these sites, such as type of hazardous waste and source of hazardous waste, is provided.

8.3.14 *A Compendium of Cost Data For Environmental Restoration Technologies, Methods, and Processes*

Youngblood, A., and C. Ulibarri. *A Compendium of Cost Data for Environmental Restoration Technologies, Methods, and Processes,*

developed for the U.S. Department of Energy by Los Alamos National Laboratory and University of New Mexico, Report No. LA-UR-91-2455, August 1991. [No secondary source identified.]

This report is a compendium of representative costs relating to the ER of sites contaminated with hazardous, radioactive, and mixed waste. Some of the costs are derived from historical site-restoration data. Other costs are estimates obtained from EPA and DOE reports, scientific journals, proceedings of professional conferences, RI/FS, and computer models.

The report focuses on ten categories of remediation operations. For each case in a category, a detailed WBS is provided. The ten categories, with the number of cases in each category given in parenthesis, are:

- RI/FS (2)
- Site Preparation (7)
- Containment/Stabilization (40)
- Excavation/Removal (40)
- Physical Treatment (82)
- Chemical Treatment (17)
- Biological Treatment (30)
- Thermal Treatment (11)
- Transportation (2)
- Disposal (13).

The report gives a range of total cost of the operation for each case. In some cases, the component costs according to a detailed WBS also are provided. All of these are given as unit costs. Also included is the Chemical Engineering Plant Cost Index for the years 1975–1991 from which present dollar costs can be computed.

8.3.15 *Low-Level and Transuranic Waste Transportation, Disposal and Facility Decommissioning Cost Sensitivity Analysis*

Schlueter, R., and J.J. Schafer. *Low-Level and Transuranic Waste Transportation, Disposal and Facility Decommissioning Cost Sensitivity Analysis,* developed for the Idaho National Engineering Laboratory, U.S. Department of Energy by EG&G Idaho, Inc., Report No. EGG-WTD-10092, May 1992, DOE-RAPIC No. 05396.

This report contains cost information associated with the transportation and disposal of LLW and TRU waste and the D&D of the processing facilities. The D&D costs for ten specific processing methods are considered:

- Melting/incineration with LLW presort
- *In situ* vitrification and retrieval processing
- Melting/incineration with LLW postsort
- Thermal treatment/solidification with LLW presort-variant 1

- Thermal treatment/solidification with LLW presort-variant 2
- Pyrolysis/acid leach with plutonium extraction
- Molten salt oxidation
- Chemical oxidation/solidification
- Sort/treat/repackage
- Volume reduction and repackaging.

Actual disposal costs and anticipated future disposal costs were obtained from DOE sites at INEL, Lawrence Livermore National Laboratory, Nevada Test Site, Hanford, Savannah River Site, Waste Isolation Pilot plant (TRU only), Rocky Flats Plant, Sandia National Laboratory, and Oak Ridge National Laboratory. Disposal cost information also was obtained from the U.S Ecology Washington and Nevada Nuclear Centers, the Barnwell Low-Level Radioactive Waste Management Facility, the Nevada Test Site, the Central Interstate Compact, the California LLW Disposal Facility, the Savannah River Site, and the Waste Isolation Pilot Plant.

Transportation costs are given for distances of 30 miles (low), 300 miles (medium), and 500 miles (high). Disposal costs are given for low, medium, and high rates of disposal. All costs are stated in terms of dollars per cubic foot of material.

The respective costs of D&D of the waste-processing facilities are determined by each facility's square footage and are given in dollars per square foot. Also given are the total costs for the processing facilities associated with each of the ten processing methods listed above.

APPENDIX A:
EM COST DATABASE/MODEL
DETAILED EVALUATION MATRICES

APPENDIX A:
EM COST DATABASE/MODEL
DETAILED EVALUATION MATRICES

Detailed Evaluation Matrix

HAZMAT Database/Model

Cost Breakdown Structure

Cost Breakdown Structure	CBS Depth Score 1	2	3	4	5
1 Environmental Program Management	44%				
.01 Program Management		50%			
.01 Program Planning			X		
.01 Compliance				X	
.02 Pollution Prevention				X	
.03 Conservation					
.04 Closure / Post Closure					
.05 Cleanup					
.02 Compliance Management					
.01 Regulatory Interaction (...reporting, permitting)					
.02 Executive Order Compliance					
.03 Environmental Law Compliance					
.04 State Statutes / State Law Compliance					
.05 Local and Municipal Law Compliance					
.06 Environmental Management Audits					
.07 Record Keeping					
.03 Pollution Prevention Management			X		
.01 Air, Water, Solids, and Noise Pollution Prevention Prgm					
.02 HTR Material Elimination/Reduction/Substitution Prgm				X	
.03 Waste Minimization Programs				X	
.04 Reuse / Recycle Programs				X	
.04 Conservation Management					
.01 Preservation of Natural Habitat					
.02 Preservation of Cultural and Archeological Resources					
.03 EIS / EA					
.XX Other			N/A		
.02 Program Support		38%			
.01 Training / Certification			X		
.01 Personnel Protection Training				X	
.02 Hazardous Communications Training				X	
.03 HTR Material and Waste Handling Training				X	
.04 Emergency Response Training				X	
.02 Public Affairs					
.03 Engineering and Administrative Support					
.01 Cost Estimate / Analysis					
.02 Cost / Schedule Control System Criteria					
.03 Engineering Network Analysis					
.04 Reports / Reviews					
.05 Subcontract Administration					
.04 Legal Support					
.01 Enforcement Actions (e.g. civil, criminal, citizens suits)					
.02 Civil Suit / Toxic Torts Defense					

Cost Driver Categories

	HTR Substances: Hazardous / Toxic							Radiological: Contact Handled				Radiological: Remote Handle			Waste Sources: Mfg, Bases, & Depot Facilities				Waste Sources: Environmental Restoration											Productivity: Personal Protection Level					Cost Risk: Medical, Liability, Regultry			Cost Risk: Tech, Scope		Cost Risk: Other	
Cost Breakdown Structure	.01	.02	.03	.04	.05	.06	.07	.01	.02	.03	.04	.01	.02	.03	.01	.02	.03	.04	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.11	.01	.02	.03	.04	.05	.01	.02	.03	.01	.02	.01	.02
.01 Program Management	X	X	X	X	X	X	X								X	X	X	X																							
.02 Program Support	X	X	X	X	X	X	X								X	X	X	X																							

Detailed Evaluation Matrix

HAZMAT Database/Model

Cost Driver Categories

Cost Breakdown Structure		CBS Depth Score 1	2	3	4	5	HTR Substances: Hazardous / Toxic (.01 .02 .03 .04 .05 .06 .07)	HTR Substances: Radiological: Contact Handled (.01 .02 .03 .04)	HTR Substances: Radiological: Remote Handle (.01 .02 .03)	Waste Sources: Mfg, Bases, & Depot Facilities (.01 .02 .03 .04)	Waste Sources: Environmental Restoration (.01 .02 .03 .04 .05 .06 .07 .08 .09 .10 .11)	Productivity: Personal Protection Level (.01 .02 .03 .04 .05)	Cost Risk: Medical, Liability, Regultry (.01 .02 .03)	Cost Risk: Tech, Scope (.01 .02)	Cost Risk: Other (.01 .02)
.05	Medical			X											
.01	Occupational Physical Examinations				X										
.02	Industrial Hygiene Surveys/Serveillance				X										
.06	Health and Safety														
.07	Quality Assurance / Quality Control														
.08	Emergency Response			X											
.XX	Other			N/A											
2	**HTR Material Management**	65%													
.01	**HTR Material Management and Support**		25%												
.01	Pollution Prevention Program Implementation			0%											
.01	HTR Material Studies														
.02	HTR Material Bench Scale Test														
.03	HTR Material Demonstration														
.04	HTR Material Conservation (recovery, reuse, recycle)														
.02	Compliance Program Implementation			50%			X X X X X X X			X X X X					
.01	Surveillance of Process Operations				X										
.02	Quality Assurance / Quality Control														
.03	Industrial Hygiene Surveys				X										
.04	Waste Management Coordination														
.XX	Other			N/A											
.02	**HTR Material Control and Distribution**		69%												
.01	Requisition / Acquisition			67%			X X X X X X X			X X X X					
.01	Process Requisitions														
.02	HTR Material Source (Recycle, Reuse, Vendor)				X										
.03	HTR Material Purchase				X										
.02	Handling / Distribution			100%			X X X X X X X					– – – – –	–		
.01	Subdivide				X										
.02	Label				X										
.03	Distribute				X										
.03	Management / Control of Use			50%			X X X X X X X			X X X X					
.01	Material Safety Data Sheets														
.02	Immediate Supervision of Process Operation				X										
.04	Recovery			100%			X X X X X X X			X X X X		– – – – –	–		
.05	Reuse			0%											
.06	Recycle			100%			X X X X X X X			X X X X		– – – – –	–		
.XX	Other			N/A											
.03	**HTR Material Management Facilities**		100%												
.01	Personnel Protection			100%			X X X X X X X			X X X X					
.01	Protection Equipment Procurement				X										
.02	Equipment Dispensing and Tracking				X										
.02	HTR Capital Facilities / Equipment			100%			X X X X X X X			X X X X					
.01	Laboratory Equipment				X										
.02	Recycling stills				X										
.03	Storage Cabinets				X										
.04	Handling Devices				X										
.05	Showers/Eye Washes				X										
.06	Exhaust / Filter Systems				X										
.XX	Other			N/A											

Detailed Evaluation Matrix

HAZMAT Database/Model

Cost Breakdown Structure	CBS Depth Score 1	2	3	4	5
3 HTR Waste Management	13%				
.01 HTR Waste Operations Management and Support		0%			
.01 Pollution Prevention Program Implementation			0%		
♦ ♦ ♦					
.02 On-site Waste Management Facility Construction / Ops		0%			
.01 Treatment Facility Design & Construction			0%		
♦ ♦ ♦					
.03 Closure and Post-Closure Care		0%			
.01 Treatment Facility Closure			0%		
♦ ♦ ♦					
.04 Off-site HTR Waste Disposal		50%			
.01 Commercial (Fee)			100%		
.02 Other than Commercial (Fee)			0%		
4 Environmental Restoration	0%				
.01 Preliminary Assessment / Site Investigation (PA/SI) and/or RCRA Facility Assessment (RFA)		0%			
♦ ♦ ♦					
5 HTR Material and Waste Transportation	25%				
.01 Transportation Management		0%			
.02 Transportation		50%			
.01 Carrier Cost			X		
.01 Truck				X	
.02 Rail					
.03 Air					
.04 Water					
.02 Transportation Equipment					
.01 Specially Equipped Trailers					
.02 Specially Equipped Railroad Cars					

Cost Driver Categories

HTR Substances	Hazardous / Toxic .01	.02	.03	.04	.05	.06	.07	Radiological: Contact Handled .01	.02	.03	.04	Remote Handle .01	.02	.03
3 HTR Waste Management														
.01 HTR Waste Operations Management and Support														
.01 Pollution Prevention Program Implementation														
.02 On-site Waste Management Facility Construction / Ops														
.01 Treatment Facility Design & Construction														
.03 Closure and Post-Closure Care														
.01 Treatment Facility Closure														
.04 Off-site HTR Waste Disposal														
.01 Commercial (Fee)	X	X	X	X	X	X	X							
.02 Other than Commercial (Fee)														
4 Environmental Restoration														
.01 Preliminary Assessment / Site Investigation (PA/SI) and/or RCRA Facility Assessment (RFA)														
5 HTR Material and Waste Transportation														
.01 Transportation Management														
.02 Transportation	X	X	X	X	X	X	X							
.01 Carrier Cost														
.01 Truck														
.02 Rail														
.03 Air														
.04 Water														
.02 Transportation Equipment														
.01 Specially Equipped Trailers														
.02 Specially Equipped Railroad Cars														

Waste Sources	Mfg, Bases, & Depot Facilities .01	.02	.03	.04	Environmental Restoration .01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.11
3 HTR Waste Management															
.01 HTR Waste Operations Management and Support															
.01 Pollution Prevention Program Implementation															
.02 On-site Waste Management Facility Construction / Ops															
.01 Treatment Facility Design & Construction															
.03 Closure and Post-Closure Care															
.01 Treatment Facility Closure															
.04 Off-site HTR Waste Disposal															
.01 Commercial (Fee)															
.02 Other than Commercial (Fee)															
4 Environmental Restoration															
.01 Preliminary Assessment / Site Investigation (PA/SI) and/or RCRA Facility Assessment (RFA)															
5 HTR Material and Waste Transportation															
.01 Transportation Management															
.02 Transportation	X	X	X	X											
.01 Carrier Cost															
.01 Truck															
.02 Rail															
.03 Air															
.04 Water															
.02 Transportation Equipment															
.01 Specially Equipped Trailers															
.02 Specially Equipped Railroad Cars															

Productivity / Cost Risk	Personal Protection Level .01	.02	.03	.04	.05	Medical, Liability, Regultry .01	.02	.03	Tech, Scope .01	.02	Other .01	.02
3 HTR Waste Management												
.01 HTR Waste Operations Management and Support												
.01 Pollution Prevention Program Implementation												
.02 On-site Waste Management Facility Construction / Ops												
.01 Treatment Facility Design & Construction												
.03 Closure and Post-Closure Care												
.01 Treatment Facility Closure												
.04 Off-site HTR Waste Disposal												
.01 Commercial (Fee)	-	-	-	-	-	-	X	X				
.02 Other than Commercial (Fee)												
4 Environmental Restoration												
.01 Preliminary Assessment / Site Investigation (PA/SI) and/or RCRA Facility Assessment (RFA)												
5 HTR Material and Waste Transportation												
.01 Transportation Management												
.02 Transportation	-	-	-	-	-	-						
.01 Carrier Cost												
.01 Truck												
.02 Rail												
.03 Air												
.04 Water												
.02 Transportation Equipment												
.01 Specially Equipped Trailers												
.02 Specially Equipped Railroad Cars												

Detailed Evaluation Matrix

RACER – ENVEST

Cost Breakdown Structure

Cost Breakdown Structure			CBS Depth Score 1	2	3	4	5
1 Environmental Program Management			0%				
.01	Program Management			0%			
♦							
♦							
♦							
2 HTR Material Management			0%				
.01	HTR Material Management and Support			0%			
.01	Pollution Prevention Program Implementation				0%		
♦							
♦							
♦							
3 HTR Waste Management			22%				
.01	HTR Waste Operations Management and Support			0%			
.01	Pollution Prevention Program Implementation				0%		
♦							
♦							
♦							
.03	Closure and Post–Closure Care			66%			
.01	Treatment Facility Closure				67%		
	.01	Inventory					
	.02	Sampling and Analysis				X	
	.03	Removal of Waste Residue				X	
	.04	Decontamination of the Unit					
	.05	Disassembly of Ancillary Piping				X	
	.06	Demolition and Removal				X	
.02	Storage Facility Closure				57%		
	.01	Inventory					
	.02	Sampling and Analysis				X	
	.03	Removal of Waste (liquid, sludge, solids)				X	
	.04	Excavation, Disassembly, and Loading				X	
	.05	Demolition and Removal of Containment System				X	
	.06	Treatment (refer to 3.02)					
	.07	Disposal (refer to 3.02 or 3.04)					
.03	Disposal Facility Closure				75%		
	.01	Inventory					
	.02	Monitoring Well Installation				X	
	.03	Sampling & Analysis				X	
	.04	Landfill Capping / Physical Completion				X	
.04	Restoration				100%		
.05	Certification of Closure				0%		
.06	Post–Closure Care				100%		
.XX	Other				N/A		

Cost Driver Categories

	HTR Substances: Hazardous / Toxic .01	.02	.03	.04	.05	.06	.07	Radiological: Contact Handled .01	.02	.03	.04	Radiological: Remote Handle .01	.02	.03	Waste Sources: Mfg, Bases, & Depot Facilities .01	.02	.03	.04	Waste Sources: Environmental Restoration .01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.11	Productivity: Personal Protection Level .01	.02	.03	.04	.05	Cost Risk: Medical, Liability, Regultry .01	.02	.03	Tech, Scope .01	.02	Other .01	.02
3.03.01 Treatment Facility Closure	X	X	X	X	X			X	X																					X	X	X	X	X							
3.03.02 Storage Facility Closure	X	X	X	X	X			X	X																					X	X	X	X	X							
3.03.03 Disposal Facility Closure	X	X	X	X	X			X	X																					X	X	X	X	X							

Detailed Evaluation Matrix

RACER – ENVEST

Cost Breakdown Structure		CBS Depth Score 1	2	3	4	5
.04	**Off-site HTR Waste Disposal**		100%			
.01	Commercial (Fee)			100%		
.02	Other than Commercial (Fee)			100%		
4	**Environmental Restoration**	53%				
.01	**Preliminary Assessment / Site Investigation (PA/SI) and/or RCRA Facility Assessment (RFA)**		22%			
.01	Preparation of Plans					
.02	Project Management / Support / Administration					
.03	Administrative Record					
.04	Community Relations					
.05	Regulatory Interaction					
.06	Field Investigation			X		
.07	Site Work / Temporary Facilities			X		
.08	Off-site Laboratory Sample Analysis			X		
.09	On-site Laboratory Sample Analysis			X		
.10	Analytical Support / Sample Management / Data Validation					
.11	Data Evaluation					
.12	Risk Assessment – Hazardous Ranking System (HRS)					
.13	Document Assessment					
.14	N/A -- (Alternative Evaluation is an FS or CMS activity)					
.15	N/A -- (Treatability Studies are RI or CMS activities)					
.16	N/A -- (Document FS or CMS)					
.17	Post Assessment Support					
.18	Enforcement					
.9X	Other			N/A		
.02	**Remedial Investigation / Feasibility Study (RI/FS) and/or RCRA Facility Investigation/Corrective Measures Study (RFI/CMS)**		100%			
.01	Preparation of Plans			X		
.02	Project Management / Support / Administration			X		
.03	Administrative Record			X		
.04	Community Relations			X		
.05	Regulatory Interaction			X		
.06	Field Investigation			X		
.07	Site Work / Temporary Facilities			X		
.08	Off-site Laboratory Sample Analysis			X		
.09	On-site Laboratory Sample Analysis			X		
.10	Analytical Support / Sample Management / Data Validation			X		
.11	Data Evaluation			X		
.12	Risk Assessment – Baseline Risk Assessment			X		
.13	Document Assessment			X		
.14	Alternative Evaluation			X		
.15	Treatability Studies			X		
.16	Document FS or CMS			X		
.17	Post Assessment Support			X		

Cost Driver Categories

HTR Substances

Cost Breakdown Structure	Hazardous / Toxic .01	.02	.03	.04	.05	.06	.07	Radiological Contact Handled .01	.02	.03	.04	Remote Handle .01	.02	.03
.04.01 Commercial (Fee)	X	X	X	X	X			X	X					
.04.02 Other than Commercial (Fee)	X	X	X	X	X			X	X					
4.01 PA/SI and/or RFA	X	X	X	X	X			X	X					
4.02 RI/FS and/or RFI/CMS	X	X	X	X	X			X	X					

Waste Sources

Cost Breakdown Structure	Mfg, Bases, & Depot Facilities .01	.02	.03	.04	Environmental Restoration .01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.11
.04.01 Commercial (Fee)															
.04.02 Other than Commercial (Fee)															
4.01 PA/SI and/or RFA					X	X	X	X	X	X		X		X	X
4.02 RI/FS and/or RFI/CMS					X	X	X	X	X	X		X		X	X

Productivity / Cost Risk

Cost Breakdown Structure	Personal Protection Level .01	.02	.03	.04	.05	Medical, Liability, Regultry .01	.02	.03	Tech, Scope .01	.02	Other .01	.02
.04.01 Commercial (Fee)	X	X	X	X	X							
.04.02 Other than Commercial (Fee)	X	X	X	X	X							
4.01 PA/SI and/or RFA												
4.02 RI/FS and/or RFI/CMS	X	X	X	X	X							

Detailed Evaluation Matrix

RACER – ENVEST

Cost Breakdown Structure

Code	Cost Breakdown Structure	CBS Depth Score 1	2	3	4	5
.18	Enforcement			X		
.9X	Other			N/A		
.03	**Remedial Design**		17%			
.01	Preparation of Plans					
.02	Project Management / Support / Administration					
.03	Administrative Record					
.04	Community Relations					
.05	Regulatory Interaction					
.06	Field Investigation			X		
.07	Site Work / Temporary Facilities			X		
.08	Off-site Laboratory Sample Analysis			X		
.09	On-site Laboratory Sample Analysis			X		
.10	Analytical Support / Sample Management / Data Validation					
.11	Data Evaluation					
.12	N/A -- (Risk Assessment is not a RD activity)					
.13	N/A -- (Document Assessment is not a RD activity)					
.14	N/A -- (Alternative Evaluation is not a RD activity)					
.15	Treatability Studies					
.16	N/A (Document FS or CMS is not a RD activity)					
.17	N/A -- (Post Assessment Support is not a RD activity)					
.18	N/A -- (Enforcement is not a RD activity)					
.19	Identification of Long Lead Items					
.20	Design Preparation (6% Limit)					
.21	Value Engineering / Special Studies					
.22	Post Design Support					
.23	A/E Support During Remedial Action					
.9X	Other			N/A		
.04	**Remedial Action**		71%			
	Preparatory			67%		
.01	Mobilization & Preparatory Work					
.01	Mobilization of Construction Equipment & Facilities					
.02	Mobilization of Personnel					
.03	Preconstruction Submittals / Implementation Plans					
.04	Setup / Construct Temporary Facilities					
.05	Construct Temporary Facilities					
.06	Temporary Relocation of Roads / Structures / Utilities					
.07	Construct Plant Erection					
.9X	Other					N/A
.02	Monitoring				X	
.01	Meteorological Monitoring					X
.02	Radiological Monitoring					X
.03	Air Monitoring and Sampling					X
.04	Monitoring Wells					X
.05	Sampling Surface Water/Groundwater/Liquid Waste					X
.06	Sampling Soil and Sediment					X

Cost Driver Categories

Code	Cost Breakdown Structure	HTR Substances: Hazardous / Toxic .01	.02	.03	.04	.05	.06	.07	Radiological: Contact Handled .01	.02	.03	.04	Remote Handle .01	.02	.03	Mfg, Bases, & Depot Facilities .01	.02	.03	.04	Waste Sources: Environmental Restoration .01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.11	Productivity: Personal Protection Level .01	.02	.03	.04	.05	Cost Risk: Medical, Liability, Regultry .01	.02	.03	Tech, Scope .01	.02	Other .01	.02
.03	**Remedial Design**	X	X	X	X	X			X	X										X	X	X	X	X	X		X		X	X	X	X	X	X	X							
.04	**Preparatory**	X	X	X	X	X			X	X										X	X	X	X	X	X		X		X	X	X	X	X	X	X							

Detailed Evaluation Matrix

RACER – ENVEST

Cost Breakdown Structure		CBS Depth Score 1	2	3	4	5
.07	Sampling Asbestos					
.08	Sampling Radioactive Contamination Media					X
.09	Laboratory Chemical Analysis					X
.10	Radioactive Waste Analysis					X
.11	Geotechnical Testing					
.12	Geotechnical Instrumentation					
.13	On–site Laboratory Facilities					X
.14	Off–site Laboratory Facilities					
.9X	Other					N/A
.03	Site Work				X	
.01	Demolition					
.02	Clearing and Grubbing					X
.03	Earthwork					
.04	Roads / Parking / Curbs / Walks					X
.05	Fencing					X
.06	Electrical Distribution					X
.07	Telephone / Communication Distribution					
.08	Water / Sewer / Gas Distribution					X
.09	Steam and Condensate Distribution					
.10	Fuel Line Distribution					
.11	Storm Drainage / Subdrainage					X
.12	Permanent Cover Structure Over Contaminated Area					X
.13	Development of Borrow Pit / Haul Roads					X
.91	Protective Action (Alt Water Supply, Pop. Protect)					X
.92	Retaining Wall					X
.9X	Other					N/A
	On–site Containment / Collection			67%		
.04	Reserved Number				N/A	
.05	Surface Water collection and Control				X	
.01	Berms / Dikes					X
.02	Floodwalls					
.03	Levees					
.04	Terraces and Benches					
.05	Excavation for Channels / Waterways					X
.06	Chutes or Flumes					
.07	Sediments Barriers					
.08	Storm Drainage					X
.09	Lagoons / Basins / Tanks / Dikes					
.10	Pumping / Draining / Collection					
.11	Transport to Treatment Plant					X
.12	Earthwork					
.13	Erosion Control					
.14	Development of Borrow Pit / Haul Roads					X
.9X	Other					N/A

Cost Driver Categories

	HTR Substances: Hazardous / Toxic .01	.02	.03	.04	.05	.06	.07	Radiological: Contact Handled .01	.02	.03	.04	Radiological: Remote Handle .01	.02	.03	Waste Sources: Mfg, Bases, & Depot Facilities .01	.02	.03	.04
On–site Containment / Collection	X	X	X	X	X			X	X									

	Waste Sources: Environmental Restoration .01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.11	Productivity: Personal Protection Level .01	.02	.03	.04	.05	Cost Risk: Medical, Liability, Regultry .01	.02	.03	Tech, Scope .01	.02	Other .01	.02
On–site Containment / Collection	X	X	X	X	X	X		X		X	X	X	X	X	X	X							

Detailed Evaluation Matrix

RACER – ENVEST

Cost Breakdown Structure

Cost Breakdown Structure		CBS Depth Score 1	2	3	4	5
.06	Groundwater				X	
.01	Extraction and Injection Wells					X
.02	Subsurface Drainage / Collection					X
.03	Slurry Walls					X
.04	Grout Curtain					
.05	Sheet Piling					
.06	Lagoons / Basins / Tanks / Dikes					
.07	Pumping / Draining / Collection					
.08	Transport To Treatment Plant					X
.09	Development of Borrow Pit/Haul Roads					X
.9X	Other (injection wells)					
.07	Air Pollution / Gas Collection & Control					
.01	Gas / Vapor Collection Trench System,					
.02	Gas / Vapor Collection Well System					
.03	Gas Collection at Lagoon Cover					
.04	Fugitive Dust / Vapor / Gas Emission Control					
.9X	Other					N/A
.08	Solids Collection And Containment					
.01	Excavation					X
.02	Waste containment, Portable (Furnish / Fill)					
.03	Transport to Treatment Plant					
.04	Radioactive Specific Waste Containment					
.05	Capping or Contaminated Area / Waste Pile					X
.06	Nuclear Waste Densification. (DYN Compact)					
.07	Development of Borrow Pit / Haul Roads					X
.9X	Other					N/A
.09	Liquids / Sediments/ Sludge Collection & Containment				X	
.01	Dredging / Excavating					
.02	Industrial Vacuuming					
.03	Waste Containment – Portable					
.04	Transport to Treatment Plant					X
.05	Radioactive Specific Waste Containment					
.06	Pumping / Draining / Collection					X
.07	Lagoons / Basins / Tanks / Dikes					X
.08	Development of Borrow Pit / Haul Roads					X
.9X	Other					N/A
.10	Drums / Tanks / Structure / Misc. Demol. Removal				X	
.01	Drum Removal					X
.02	Tank Removal					X
.03	Structure Removal					
.04	Asbestos Abatement					
.05	Ordinance Removal					
.06	Radioactive Specific Waste Containment					
.07	Misc. Items					
.9X	Other					N/A

Cost Driver Categories

HTR Substances	Hazardous / Toxic	.01 .02 .03 .04 .05 .06 .07
HTR Substances	Radiological – Contact Handled	.01 .02 .03 .04
HTR Substances	Radiological – Remote Handle	.01 .02 .03
Waste Sources	Mfg, Bases, & Depot Facilities	.01 .02 .03 .04
Waste Sources	Environmental Restoration	.01 .02 .03 .04 .05 .06 .07 .08 .09 .10 .11
Productivity	Personal Protection Level	.01 .02 .03 .04 .05
Cost Risk	Medical, Liability, Regultry	.01 .02 .03
Cost Risk	Tech, Scope	.01 .02
Cost Risk	Other	.01 .02

Detailed Evaluation Matrix

RACER – ENVEST

Cost Breakdown Structure			CBS Depth Score 1	2	3	4	5
Treatment					100%		
.11		Biological Treatment				X	
	.01	Activated Sludge					
	.02	Rating Biological Contractors					
	.03	Land Treatment					X
	.04	In–Situ Biodegradation / Bioreclamation					X
	.05	Trickling Filter					X
	.06	Biological Lagoons					
	.07	Composting					
	.08	Sludge Stabilization – Aerobic					
	.09	Sludge Stabilization – Anaerobic					
	.10	Genetically Engineered Organisms					
	.11	White Rot Fungus					
	.12	Slurry Biodegradation					X
	.9X	Other					N/A
.12		Chemical treatment				X	
	.01	Oxidation / Reduction (Catalytic)					
	.02	Solvent Extraction					X
	.03	Chlorination					
	.04	Ozonation					
	.05	Ion Exchange					
	.06	Neutralization					X
	.07	Chemical Hydrolysis					
	.08	Ultraviolet Photolysis					
	.09	Dehalogenation (Catalytic Dechlorination)					
	.10	Alkali Metal Dechlorination					
	.11	Alkali Metal / Polyethylene Glycol					
	.12	Base–Catalyzed Decomposition Process					
	.13	Electrolysis					
	.9X	Other					N/A
.13		Physical Treatment				X	
	.01	Filtration / Ultrafiltration					X
	.02	Sedimentation					
	.03	Straining					
	.04	Coagulation / Flocculation / Precipitation					X
	.05	Equalization					
	.06	Evaporation					
	.07	Air Stripping					X
	.08	Steam Stripping					
	.09	Soil Washing (Surfactant / Solvent)					X
	.10	Soil Flushing (Surfactant / Solvent)					X
	.11	Solids Dewatering					
	.12	Oil / Water Separation					X
	.13	Dissolved Air Floatation					
	.14	Heavy Medial Separation					

Cost Driver Categories

			.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.11
HTR Substances	Hazardous / Toxic	Treatment	X	X	X	X	X						
HTR Substances	Radiological – Contact Handled	Treatment	X	X									
HTR Substances	Radiological – Remote Handle	Treatment											
Waste Sources	Mfg, Bases, & Depot Facilities	Treatment											
Waste Sources	Environmental Restoration	Treatment	X	X	X	X	X	X		X		X	X
Productivity	Personal Protection Level	Treatment	X	X	X	X	X						
Cost Risk	Medical, Liability, Regultry	Treatment											
Cost Risk	Tech, Scope	Treatment											
Cost Risk	Other	Treatment											

Detailed Evaluation Matrix

RACER – ENVEST

	Cost Breakdown Structure	CBS Depth Score 1	2	3	4	5
.15	Distillation					
.16	Chelation					
.17	Solvent Extraction					
.18	Supercritical Extraction					
.19	Carbon Absorption–Gases					X
.20	Carbon Absorption–Liquids					X
.21	Membrane Separation–Reverse Osmosis					
.22	Electrodialysis					
.23	Vapor Extraction					X
.24	Shredding					
.25	Aeration					X
.26	Advanced Electrical Reactor					
.27	Low–Level Waste (LLW) Compaction					
.28	Agglomeration					
.29	In–Situ Steam Extraction					
.30	Filter Presses					
.31	Lignin Absorption / Sorptive Clays					
.9X	Other					N/A
.14	Thermal Treatment				X	
.01	Incineration					X
.02	Low Temperature Thermal Desorption					X
.03	Supercritical Water Oxidation					
.04	Molten Salt Destruction					
.05	Detonation					
.06	Solar Detoxification					
.9X	Other					N/A
.15	Stabilization/Fixation/Encapsulation				X	
.01	Molten Glass					
.02	In–Situ Vitrification					X
.03	In–situ Pozzolan Process (Lime/Portland Cement)					
.04	Pozzolan Process (Lime/Portland Cement)					X
.05	Asphalt–Based Encapsulation					
.06	Radioactive Waste Solidification					
.07	Sludge Stabilization (Aggrgate/Rock/Slag)					X
.9X	Other					N/A
.16	Reserved Number				N/A	
	Decontamination and Decommissioning			67%		
.17	Decontamination and Decommissioning (facility)					
.01	Pre–Decommissioning Operations					
.02	Facility Shutdown Activities					
.03	Procurement of Equipment & Material					
.04	Dismantling Activities					
.05	Research & Development					
.06	Spent Fuel Handling					
.07	Hot Cell Cleanup					

Cost Driver Categories

Cost Breakdown Structure	HTR Substances: Hazardous / Toxic .01	.02	.03	.04	.05	.06	.07	Radiological: Contact Handled .01	.02	.03	.04	Radiological: Remote Handle .01	.02	.03	Waste Sources: Mfg, Bases, & Depot Facilities .01	.02	.03	.04	Environmental Restoration .01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.11	Productivity: Personal Protection Level .01	.02	.03	.04	.05	Cost Risk: Medical, Liability, Regultry .01	.02	.03	Tech, Scope .01	.02	Other .01	.02
Decontamination and Decommissioning	X	X	X	X	X			X	X																					X	X	X	X	X							

Detailed Evaluation Matrix

RACER – ENVEST

Cost Breakdown Structure

	Cost Breakdown Structure	CBS Depth Score 1	2	3	4	5
.91	Ancillary Structures D&D (Pavement, Pipe)				X	
.92	Equipment / Personnel Decontamination				X	
.9x	Other					N/A
	Off-site Treatment / Disposal			100%		
.18	Disposal (Other than Commercial)				X	
.01	Storage / Disposal Facility Construction / Operations					X
.02	Container Handling					X
.03	Transport to Storage / Disposal Facility					X
.04	Sorting					
.05	Spreading					
.06	Compacting					
.07	Placement					
.08	Final Closure					
.09	Disposal Fees and Taxes					X
.10	Mixed Waste Storage Fees & Taxes					
.91	Treatment					X
.9X	Other					N/A
.19	Disposal (Commercial)				X	
.01	Container Handling					X
.02	Transport to Storage / Disposal Facility					X
.03	Disposal Fees and Taxes					X
.91	Treatment					X
.9X	Other					N/A
	Physical Completion / Closure			25%		
.20	Site Restoration				X	
.01	Earthwork					X
.02	Permanent Markers					
.03	Re-establish Roads / Structure / Facilities					
.04	Revegetation and Planting					X
.05	Removal of Barriers					
.06	Post-Construction Maintenance					X
.9X	Other					N/A
.21	Demobilization (Construction)					
.01	Removal of Temporary Facilities					
.02	Removal of Temporary Utilities					
.03	Final Decontamination					
.04	Demobilization Construction Equip. and Facilities					
.05	Demobilization of Personnel					
.06	Post-Construction Submittals					
.07	Construction Plant Takedown					
.9X	Other					N/A
.91	Certification of Closure					
.92	Post-Closure Care					
.9x	Other				N/A	

Cost Driver Categories

Cost Breakdown Structure	HTR Substances: Hazardous / Toxic .01	.02	.03	.04	.05	.06	.07	Radiological: Contact Handled .01	.02	.03	.04	Radiological: Remote Handle .01	.02	.03	Waste Sources: Mfg, Bases, & Depot Facilities .01	.02	.03	.04	Waste Sources: Environmental Restoration .01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.11	Productivity: Personal Protection Level .01	.02	.03	.04	.05	Cost Risk: Medical, Liability, Regultry .01	.02	.03	Cost Risk: Tech, Scope .01	.02	Cost Risk: Other .01	.02
Off-site Treatment / Disposal	X	X	X	X	X			X	X																					X	X	X	X	X							
Physical Completion / Closure																																									

Detailed Evaluation Matrix

RACER – ENVEST

Cost Breakdown Structure	CBS Depth Score					HTR Substances: Hazardous / Toxic							Radiological: Contact Handled				Radiological: Remote Handle		
	1	2	3	4	5	.01	.02	.03	.04	.05	.06	.07	.01	.02	.03	.04	.01	.02	.03
5 HTR Material and Waste Transportation	25%																		
.01 Transportation Management		0%																	
.02 Transportation		50%				X	X	X	X	X			X	X					
.01 Carrier Cost			X																
.01 Truck				X															
.02 Rail																			
.03 Air																			
.04 Water																			
.02 Transportation Equipment																			
.01 Specially Equipped Trailers																			
.02 Specially Equipped Railroad Cars																			

Cost Breakdown Structure	Waste Sources: Mfg, Bases, & Depot Facilities				Waste Sources: Environmental Restoration											Productivity: Personal Protection Level					Cost Risk: Medical, Liability, Regultry			Cost Risk: Tech, Scope		Cost Risk: Other	
	.01	.02	.03	.04	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.11	.01	.02	.03	.04	.05	.01	.02	.03	.01	.02	.01	.02
5 HTR Material and Waste Transportation																											
.01 Transportation Management																											
.02 Transportation					X	X	X	X	X	X		X		X	X	X	X	X	X	X							
.01 Carrier Cost																											
.01 Truck																											
.02 Rail																											
.03 Air																											
.04 Water																											
.02 Transportation Equipment																											
.01 Specially Equipped Trailers																											
.02 Specially Equipped Railroad Cars																											

APPENDIX B: COST BREAKDOWN STRUCTURE/ COST DRIVER CATEGORY DICTIONARY

APPENDIX B: COST BREAKDOWN STRUCTURE/ COST DRIVER CATEGORY DICTIONARY

Changes have been made to both the Cost Breakdown Structure (CBS) and the Cost Driver Category (CDC) since they appeared in the *Environmental Management Category Report*. The only significant changes are:

- CBS 3.0 HTR Waste Management: The facility closure subelement was promoted to the second level (CBS 3.03 Closure and Post-Closure Care) from the third level (under CBS 3.02 On-Site Waste Management Facility Construction/Operations).
  - The subordinate elements to CBS 3.02 On-Site Waste Management Facility Construction/Operations have been reworked to accommodate the new element, CBS 3.03 Closure and Post-Closure Care.
  - The Construction/Operations subelements of 3.02 have been separated. For example, what had been CBS 3.02.01 Treatment Facility Construction/Operations is now separated into two subelements
    - CBS 3.02.01 Treatment Facility Design & Construction
    - CBS 3.02.02 Treatment Operations and Equipment Maintenance.
- CDC D.0 Mode of Transportation. This element has been eliminated as a cost driver category and added as lower-level activities under DBS 5.0 HTR Materials and Waste Transportation.

1.0	**Environmental Program Management**

Definition:

Environmental Program Management includes the development of plans and programs associated with environmental pollution prevention, compliance, and conservation. It also includes the professional support functions associated with these plans, programs and other environmental management activities.

The Program Management and Program Support elements are the business infrastructure of professional labor and are relatively insensitive to specific manufacturing/ maintenance processes being conducted at the facility. Most of the activities included in this category are generally indirect or part of the facility overhead.

Subordinate Elements:

1.01 Program Management
1.02 Program Support

Notes:

The activities included in Environmental Program Management are often considered to be overhead functions (included in the indirect cost accounting pool) and are not readily separable by MDAP. These CBS elements should be given specific consideration during the development of an MDAP LCC estimate and/or other cost analyses. For example, special MDAP requirements such as new facility construction may require additional Environmental Program Management resources.

1.01	**Program Management**

Definition:

Program management includes activities performed by professional staff to develop plans and programs to manage, procure, distribute, control, treat, store, dispose, and monitor HTR materials and waste. This element provides the program management activities that deal most directly with these HTR environmental requirements.

Subordinate Elements:

1.01.01 Program Planning

Examples:
- Compliance
- Pollution Prevention
- Conservation
- Closure/Post Closure
- Cleanup

1.01.02 Compliance Management

Examples:
- Regulatory Interaction (e.g. Reporting, Permitting)
- Executive Order Compliance
- Environmental Law Compliance (e.g. Air, Water, Solids, and Noise)
- State Statutes/State Law Compliance
- Local & Municipal Law Compliance
- Environmental Management Audits
- Record Keeping

1.01.03 Pollution Prevention Management

Examples:
- Air, Water, Solids, and Noise Pollution Prevention Programs
- HTR Material Elimination/Reduction/Substitution Programs
- Waste Minimization Program
- Reuse/Recycle Programs

1.01.04 Conservation Management

Examples:
- Preservation of Natural Habitat
- Preservation of Cultural and Archeological Resources
- Environmental Impact Statement and Environmental Assessments

1.01.9X Other

Notes:

Program Management is separated from Program Support to provide visibility to those management activities more directly related to Compliance, Pollution Prevention, and Conservation, and cleanup.

1.02	**Program Support**

Definition:
This element includes the legal, medical, and other professional support which can be affected by HTR material and waste management activities. These support activities include several program support functions required to conduct any program (including environmental programs) such as systems engineering, cost and schedule estimating, financial management, contracting activities and others. The other activities included in this element provide support for those areas most likely to be impacted by the environmental management requirements or by responding to environmental conditions, and provide public and private sector policy liaison.

Subordinate Elements:
1.02.01 Training/Certification
Examples:
- Personal Protection Training
- Hazardous Communication Training
- HTR Material & Waste Handling Training
- Emergency Response Training

1.02.02 Public Affairs
1.02.03 Engineering and Administrative Support
Examples:
- Cost Estimate/Analysis
- Cost/Schedule Control System Criteria
- Engineering Network Analysis
- Reports/Reviews
- Subcontract Administration

1.02.04 Legal Support
Examples:
- Enforcement Actions (eg. civil, criminal, citizen suits)
- Civil Suit/Toxic Torts Defense

1.02.03 Medical
Examples:
- Occupational Physical Examinations
- Industrial Hygiene Surveys/Surveillance

1.02.04 Health & Safety
1.02.05 Quality Assurance/Quality Control
1.02.06 Emergency Response
1.02.9X Other

Notes:
This element is included in the CBS for consideration and/or incorporation, as appropriate, in life cycle cost estimates, but are less sensitive to specific HTR material management decisions than the Program Management element.

2.0	**HTR Material Management**

Definition:

This element addresses the hands-on management and control of HTR materials for each phase (or a portion thereof) of the life cycle of weapons system programs and projects that involve the use of HTR materials. This element also includes activities that implement pollution prevention and compliance initiatives including construction or acquisition of facilities and/or equipment unique to HTR materials.

Subordinate Elements:

2.01 HTR Material Management and Support
2.02 HTR Material Control and Distribution
2.03 HTR Material Management Facilities

Notes:

The activities included under HTR Material Management are considered to be directly associated with a given MDAP. Although this element is direct, costs associated with it may not be separable because many of these activities are facility oriented and are performed in a batch process with other MDAPs.

2.01	**HTR Material Management and Support**

Definition:

This element specifically includes activities that implement pollution prevention and compliance initiatives developed under program management. The activities to implement pollution prevention and compliance programs are directly correlated to the particular MDAP generating the requirement.

Subordinate Elements:

2.01.01 Pollution Prevention Program Implementation

Examples:

- HTR Material Studies
- HTR Material Bench Scale Test
- HTR Material Demonstration
- HTR Material Conservation (Recovery, Reuse, Recycle)

2.01.02 Compliance Program Implementation

Examples:

- Surveillance of Process Operations
- Quality Assurance/Quality Control
- Industrial Hygiene Surveys
- Waste Management Coordination

2.01.XX Other

Notes:

These activities are primarily the implementation of the plans and programs established under CBS 1.0.

2.02	**HTR Material Control and Distribution**

Definition:

This element implements the programs to control and distribute HTR materials. This element has been referred to as a HTR material pharmacy because the strict controls of HTR materials is analogous to the control of pharmaceuticals. At some DoD installations, in order to acquire HTR materials, the user must present a requisition form displaying a certification to handle these materials as well as the reason for their use and the expected quantity required. This element also implements pollution prevention initiatives specific to the conservation of HTR materials through programs such as recycling.

Subordinate Elements:

2.02.01 Requisition/Acquisition
- Process requisitions
- HTR Material Source (Recycle, Reuse, Vendor)
- HTR Material Purchase

2.02.02 Handling/Distribution
- Subdivide
- Label
- Distribute

2.02.03 Management/Control of Use
- Material Safety Data Sheets
- Immediate Supervision of Process Operations

2.02.04 Recovery

2.02.05 Reuse

2.02.06 Recycle

2.02.9X Other

Notes:

These activities are associated with the strict management and control of HTR materials. The process of acquiring and controlling the use of these materials is similar to that of the medical pharmacy industry.

2.03	**HTR Material Management Facilities**

Definition:

HTR Material Management Facilities include any specific or peculiar equipment or facility required to handle, control or use HTR materials. Examples include personnel protection equipment, and installation and use of a ventilation system and/or filtering system.

Subordinate Elements:

2.03.01 Personal Protection

Examples:

- Protection Equipment Procurement
- Equipment Dispensing & Tracking

2.03.02 HTR Capital Facilities/Equipment

- Laboratory Equipment
- Recycling Stills
- Storage Cabinets
- Handling Devices
- Showers/Eye Washes
- Exhaust/Filter Systems

2.03.9X Other

Notes:

Only those facilities unique to HTR material management are included in this element. All facilities dealing with HTR waste steams are included in HTR Waste Management (CBS 3.0).

3.0	**HTR Waste Management (On-Site and/or Off-Site)**

Definition:

HTR Waste Management includes taking custody of the generated waste streams and conducting all HTR waste treatments, storage, and disposal activities required, whether the activity is an extensive on-site operation or simply off-site disposal.

Subordinate Elements:

3.01 HTR Waste Operations Management and Support
3.02 On-Site Waste Management Facility Construction/Operations
3.03 Closure and Post-Closure Care
3.04 Off-site HTR Waste Disposal

Notes:

This element includes all activities associated with HTR substance management. The HTR waste may have been produced during a process operation or may be generated by the disposal of an HTR Material. The disposal in this case is specific to waste streams and does not include environmental restoration waste which is included under Remedial Action and/or Corrective Measures (CBS 4.0).

3.01	**HTR Waste Operations Management and Support**

Definition:

This element addresses the hands-on management and control of HTR waste streams for each phase (or a portion thereof) of the life cycle of weapons system programs and projects that generate HTR waste. This element specifically includes activities that implement pollution prevention (see notes below) and compliance management initiatives developed under Environmental Program Management (CBS 1.0).

Subordinate Elements:

3.01.01 Pollution Prevention Program Implementation

Examples:

- Waste Operations Studies
- Waste Operations Bench Scale Tests
- Waste Operations Demonstration
- Waste Operations Decision Support
- Waste Preparation
- Waste Monitoring

3.01.02 Compliance Program Implementation

Examples:

- Interface with Waste Generator
- Waste Assessment/Characterization
- Waste Stream Control
- Quality Assurance/Quality Control

3.01.9X Other

Notes:

Pollution Prevention as it applies to HTR Waste Management primarily consists of waste minimization programs. Activities such as bench scale tests are implemented to test treatment technologies that can reduce the volume and/or toxicity of the process waste streams.

The activities included under HTR Waste Management are considered to be directly associated with a given MDAP. Although this element is direct, some cost associated with it may not be separable because they are facility oriented and are performed in a batch process with other MDAPs.

3.02	On-site Waste Management Facility Construction / Operations
Definition: This element includes the construction and operations of treatment, storage, and disposal facilities that deal with HTR waste. The treatment facility may include several technologies such as biological, chemical, physical, thermal and stabilization. The storage facilities may be constructed for long-term, short-term and temporary requirements. The disposal facilities include RCRA Landfills, Shallow Disposal Facilities and Engineered Disposal Facilities. Facility closure activities are included for all treatment, storage and disposal facilities mentioned above.	

Subordinate Elements:

3.02.01 Treatment Facility Design & Construction

<u>Examples:</u>

- Aqueous Waste Treatment
  - Studies and Bench Scale Test/Demonstration
  - Facility Design & Construction
  - Equipment Installation
  - Facility Start-up
- Incineration
  - Studies and Bench Scale Test/Demonstration
  - Facility Design & Construction
  - Equipment Installation
  - Facility Start-up
- Organic Removal
  - Studies and Bench Scale Test/Demonstration
  - Facility Design & Construction
  - Equipment Installation
  - Facility Start-up
- Deactivation
  - Studies and Bench Scale Test/Demonstration
  - Facility Design & Construction
  - Equipment Installation
  - Facility Start-up
- Mercury Separation
  - Studies and Bench Scale Test/Demonstration
  - Facility Design & Construction
  - Equipment Installation
  - Facility Start-up
- Grout Stabilization
  - Studies and Bench Scale Test/Demonstration
  - Facility Design & Construction
  - Equipment Installation
  - Facility Start-up
- Recycle
  - Studies and Bench Scale Test/Demonstration
  - Facility Design & Construction
  - Equipment Installation
  - Facility Start-up

3.02.02 Treatment Operations and Equipment Maintenance

<u>Examples:</u>

- Aqueous Waste Treatment
- Incineration
- Organic Removal
- Deactivation
- Mercury Separation

3.02.03 Storage Facility Design and Construction

Examples:

- Studies and Bench Scale Test/Demonstration
- Facility Design & Construction
- Equipment Installation
- Facility Start-up

3.02.04 Storage Operations and Equipment Maintenance

Examples:

- Receiving & Inspection
- Assay, sort & Packaging
- Certification/Prepare for Shipping

3.02.05 Disposal Facility Design and Construction

Examples:

- Studies and Bench Scale Test/Demonstration
- Facility Design & Construction
- Equipment Installation
- Facility Start-up

3.02.06 Disposal Operations and Equipment Maintenance

Examples:

- Container Handling
- Sorting
- Spreading
- Compacting
- Placement
- Monitor/Sample

3.02.9X Other

Notes:

This element includes all handling of HTR wastes with the exception of HTR Off-Site Waste Disposal (CBS 3.04).

3.03	**Closure and Post-Closure Care**

Definition:
This element include all activities to accomplish the final RCRA closure of the HTR waste treatment facilities. It includes both clean closures and close-in-place procedures. For example, the closure of an underground storage tank may include removal of the tank and restoration of the site, or simply removal of the hazardous substances and leaving the tank in place. The post-closure care includes continued monitoring and sampling of the site if required.

Subordinate Elements:
3.03.01 Treatment Facility Closure
Examples:
- Inventory
- Sampling and Analysis
- Removal of Waste Residue
- Decontamination of the Unit
- Disassembly of Ancillary Piping
- Demolition and Removal

3.03.02 Storage Facility Closure
Examples:
- Inventory
- Sampling and Analysis
- Removal of Waste (liquid, sludge, solids)
- Excavation, Disassembly, and Loading
- Demolition and Removal of Containment System
- Treatment (refer to 3.02)
- Disposal (refer to 3.02 and 3.04)

3.03.03 Disposal Facility Closure
Examples:
- Inventory
- Monitoring Well Installation
- Sampling and Analysis
- Landfill Capping/Physical Completion

3.03.04 Restoration
3.03.05 Certification of Closure
3.03.06 Post-Closure Care
3.03.9x Other

Notes:
This element assumes that the facility is in compliance and that there are no spills or other causes for environmental restoration. CBS 4.0 addresses all environmental restorations and corrective measure activities.

3.04	Off-Site HTR Waste Disposal
Definition: This element includes the payment of fees to either commercial or other than commercial (Government owned) disposal operations. The loading and transportation cost of these wastes may be included in the disposal fee. If it is not then this task should be included in the HTR Materials and Waste Transportation (CBS 5.0).	
Subordinate Elements: 3.04.01 Commercial (Fee) 3.04.02 Other than Commercial (Fee) 3.04.XX Other	
Notes: This element does not include disposal of waste acquired from environmental restoration programs.	

4.0	**Environmental Restoration/Corrective Measures**

Definition:

This element includes site investigations, studies, design, and cleanup activities under both RCRA and CERCLA required to restore polluted sites.

Subordinate Elements:

4.01 Preliminary Assessment / Site Investigation (PA/SI) and/or RCRA Facility Assessment (RFA)
4.02 Remedial Investigation / Feasibility Study (RI/FS) and/or RCRA Facility Investigation / Corrective Measures Study (RFI/CMS)
4.03 Remedial Design
4.04 Remedial Action and/or Corrective Measures

Notes:

This category of the CBS is taken directly without change from the final draft Work Breakdown Structure (WBS) developed by the Interagency Cost Estimating Group (ICEG). The ICEG is an informal ad-hoc group with representatives from Department of Defense, the Department of Energy, the Environmental Protection Agency, and other agencies. This WBS is currently in a formal interagency review and approval process. The US Navy and the US Army Corps of Engineers are currently use this WBS to contract specific environmental restoration projects. The complete Environmental Restoration/Corrective Action WBS, adapted from the ICEG, is provided in appendix B of this report.

4.01	**Preliminary Assessment/Site Investigation (PA/SI) and/or RCRA Facility Assessment (RFA)**

Definition:

This element includes the activities involved in the first stage in site restoration. The PA/SI phase under CERCLA or the RFA under RCRA is conducted to evaluate all known information about the site. This preliminary assessment is limited and usually non-intrusive. It is conducted to determine the nature and extent of contamination at the site, and to determine if further action or investigation is appropriate.

Notes:

The subordinate elements to this section are listed in appendix B within the *Composite Work Breakdown Structure* under column .01.

4.02	**Remedial Investigation/Feasibility Study (RI/FS) and/or RCRA Facility Investigation/Corrective Measures Study (RFI/CMS)**

Definition:

RI under CERCLA or the RFI under RCRA is conducted to fully characterize the waste site to determine the nature and extent of contamination at the site and to determine the current and future threat to the environment and human health. Treatability investigations may be conducted to verify the effectiveness of candidate treatment technologies.

The FS under CERCLA and the CMS under RCRA are conducted to identify the alternatives for remediation and to select and describe a remedial action that satisfies the applicable or relevant and appropriate requirements for mitigating the contamination.

Notes:

The subordinate elements to this section are listed in appendix B within the *Composite Work Breakdown Structure* under column .02.

4.03	**Remedial Design**

Definition:

This element includes the engineering design activities to develop drawings and specifications required to implement the chosen remedial alternative.

Notes:

The subordinate elements to this section are listed in appendix B within the *Composite Work Breakdown Structure* under column .02.

4.04	**Remedial Action and/or Corrective Measures**

Definition:

This element includes all cleanup activities associated with the contaminated site. These activities include removal actions, emergency response actions, interim remedial actions, remedial (or corrective) actions, and long-term monitoring. This element usually involves implementing, monitoring, and overseeing cleanup activities and ensuring that the remedy is constructed properly and in conformance with Remedial Design plans and is not completed until all closure requirements are met.

Notes:

The subordinate elements to this section include all the line items listed in appendix B under the HTRW Remedial Action March 1992 Work Breakdown Structure under Construction Specifications Institute (CSI) code 33.

5.0	**HTR Material & Waste Transportation**
Definition: This element includes activities to manifest, permit, load, transport, and unload HTR materials and waste throughout the life cycle of the weapon system.	
Subordinate Elements: 5.01 Transportation Management 5.02 Transportation	
Notes: The activities reported under this element are pervasive throughout the HTR Material Management, HTR Waste Management and Environmental Restoration/Corrective Measures activities above, but are separated here for independent consideration.	

A. HTR Substances

A.1 Hazardous/Toxic
- .01 Flammable
- .02 Corrosive
- .03 Reactive
- .04 Poisonous/Toxic
- .05 Oxidizer
- .06 Explosive
- .07 Prohibited

A.2 Contact-Handled Radiological
- .01 Low-Level
- .02 Low-Level Mixed
- .03 Alpha Low-Level
- .04 Alpha Low-Level Mixed

A.3 Remote handled Radiological
- .01 Alpha Low-Level
- .02 Alpha Low-Level Mixed
- .03 Transuranic (TRU)

B. HTR Waste Sources

B.1 Process Waste Streams
- .01 Manufacturing Facility
- .02 Operational Bases
- .03 Depot Facilities
- .04 Other Process Waste Streams

B.2 Environmental Restorations
- .01 Landfill
- .02 Waste Piles
- .03 Tanks, Drums, and Loose Debris
- .04 Structural Decontamination and Decommissioning
- .05 Pits and Trenches
- .06 Buried Tanks/Drums
- .07 Lakes and Ponds
- .08 Swamps, Lagoons and Impoundments
- .09 River and Streams
- .10 Groundwater
- .11 Undisturbed Soil

C. Personnel Protection Levels

C.1 Protection Level - A
Positive Pressure Breathing Apparatus and Fully Encapsulated Suit

C.2 Protection Level - B
Positive Pressure Breathing Apparatus and Chemical Resistant Suit

C.3 Protection Level - C

Respirator and Chemical Resistant Suit

C.4 Protection Level - D
Normal Work Uniforms and No Special Protection

C.5 Protection Level - E (or D+)
Gloves, Goggles, Tyvek Suits, Steel-Toed Boots and Hard Hats

D. Environmental Management Cost Risk

- D.1 Medical Risk (Exposure/Illness Loss of Time)
- D.2 Liability Damages Risk
  - .01 Toxic Torts
  - .02 Real Property Devaluation Calculation
  - .03 Contaminated Groundwater Calculation
  - .04 Natural Resource Damages
- D.3 Regulatory Compliance Risk
- D.4 Technology Risk
- D.5 Scope Risk
- D.6 Other Risk
  - .01 Cost Ranges
  - .02 Unknown

5.4 Definitions of HTR Substances

Hazardous/Toxic - are materials and wastes that may have adverse effects on the environment or on the health and safety of exposed individuals. "Hazardous" refers to a potential danger to the environment or human health. "Toxic" refers to a present danger to human health. These two conditions are closely related and are not separately defined. Brief definitions of the hazardous/toxic substance categories are provided below.

Flammable includes any solid, liquid, vapor, or gas that ignites easily and burns rapidly. Solid flammables include dusts and powders, such as charcoal and aluminum, and low-ignition-point materials. According to the Department of Transportation (DOT), flammable liquids include any liquid that provides enough vapor to ignite at temperatures lower than 141°F. Flammable gases ignite easily and may be explosive if confined in a canister or cylinder.

Corrosive includes substances that causes the deterioration of other materials. A corrosive may disintegrate metal, body tissue, plastics, or other materials. Corrosives can be in a solid, liquid, or gas form. The strength of a corrosive liquid is generally measured by its Ph number (1-14).

Reactive includes substances that undergo a violent reaction when they come in contact with water or are otherwise normally unstable. Examples of reactives include organic peroxides, pyrophorics, or water-reactives.

Poisonous/toxic includes substances that can cause health hazards by damaging living cells and tissues. Each unique chemical compound possesses inherent properties that determine the type and degree of hazard it represents. These materials include pesticides, herbicides, some solvents, asbestos, mercury, lead, polychlorinated biphenyls (PCBs), and heavy metals. Toxic chemicals include carcinogens, mutagens, teratogens, systemic poisons, asphyxiants, irritants, and allergic sensitizers.

Oxidizer includes substances able to supply oxygen chemically or supplement oxygen with other oxidizing gases enabling the support of fire. Oxidizers can exist in a solid, liquid, or gas form. Fires supported by pure or highly concentrated oxidizers are extremely difficult to control and extinguish. Oxidizers can also produce toxic materials during decomposition. Common oxidizers include, chlorates, pool chlorinators, peroxides, and nitrates.

Explosive includes substances that undergo a very rapid chemical transformation with a violent release of pressure and heat. Some explosives can be detonated by shock, heat, or friction, while others are less volatile and need a booster to detonate.

Prohibited includes substances that are or will be illegal for use throughout the DoD. Examples include, ozone-depleting compounds such as freon-12, which cannot be purchased after 1995, and freon-22, which cannot be purchased after 2005.

Radioactive Waste

Contact Handled Radioactive Waste - waste or waste containers whose external dose rate does not exceed 200 μrem/hr Most of this waste is alpha-emitting; therefore, the waste package provides sufficient containment and the packages are designated as contact handled. (Integrated Data Base for 1991: DOE/RW-0006, Rev. 7, October 1991.)

- Low-Level - Waste that contains radioactivity and is not classified as high-level waste. TRU waste, or spent nuclear fuel or 11(e)2 byproduct material as defined by DOE Order 5820.2A. Test specimens or fissionable material irradiated for research and development only, and not for the production of power or plutonium, may be classified as low-level waste, provided the concentration of TRU is less than 100 nCi/g.

- Low-Level Mixed - Waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act, respectively. Waste that satisfies the definition of LLW in the Low-Level Radioactive Waste Policy Amendments of 1985 and contains hazardous waste that has at least one of the following characteristics: (1) is listed as a hazardous waste in Subpart D of 40 CFR Part 261, (2) exhibits any of the hazardous waste characteristics identified in Subpart C of 40 CFR Part 261, or (3) contains PCB-containing waste subject to regulation under TSCA and 40 CFR Parts 702-799. (Integrated Data Base for 1991: DOE/RW-0006, Rev. 7, October 1991 and DOE Order 5820.2A.)

- Alpha Low-Level - LLW containing alpha-emitting TRU isotopes in concentrations less than 100 nCi/g or contaminated with alpha-emitting radionuclides other than depleted or natural Uranium or slightly enriched Uranium. (Reference: Integrated Data Base for 1993: DOE/RW-0006, Rev. 9, March 1994.)

- Alpha Low-Level Mixed - Mixed LLW containing a concentration between 10 and 100 nCi/g or TRU nuclides.

Remote-Handled Radioactive Waste - waste or waste containers whose external dose rate does exceeds 200 mrem/hr and contains sufficient penetrating beta, gamma, and neutron radiation. Test specimens of fissionable material irradiated for research and development purposes only and not for the production of power or plutonium may be classified as remote-handled transuranic waste. (Integrated Data Base for 1991: DOE/RW-0006, Rev. 7, October 1991 and DOE Order 5920.2A.)

- Alpha Low-Level - same as above except the surface dose rate is greater than 200 mrem.hr.

- Alpha Low-Level Mixed - same as above except the surface dose rate is greater than 200 mrem/hr.

TRU waste refers to waste materials containing elements with atomic numbers greater than 92. These elements are generally alpha-emitting radionuclides with half-lives greater than 20 years. To be transuranic, these waste materials must contain transuranic elements in quantities greater than 100 nCi/g of waste material.

APPENDIX C:
BIBLIOGRAPHY

APPENDIX C: BIBLIOGRAPHY

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APPENDIX D:
ACRONYMS AND ABBREVIATIONS

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ANG	Air National Guard
CBS	Cost Breakdown Structure
CDC	Cost Driver Categories
CER	Cost Estimating Relationship
CERCLA	Comprehensive Environmental Response, Compensation & Liability Act
CLIN	Contract Line Item Number
CORA	Cost of Remedial Action [model]
CMS	Corrective Measures Study
D&D	Decontamination and Decommissioning
DAB	Defense Acquisition Board
DoD	[U.S.] Department of Defense
DOE	[U.S.] Department of Energy
DRMS	Defense Reutilization and Marketing Service
EBUCES	Environmental Bottom-up Cost Estimating System
ECES	Environmental Cost Element Structure
EM	Environmental Management
EPA	[U.S.] Environmental Protection Agency
ER	Environmental Restoration
FS	Feasibility Study
ft^2	Square Feet
FY	Fiscal Year
HAZMAT	HAZardous MATerials Life Cycle Estimator
HCAS	Historical Cost Analysis System
HMLCCM	Hazardous Material Life-Cycle Cost Model
HTR	Hazardous, Toxic, and Radiological
HTRW	Hazardous, Toxic, and Radiological Waste
INEL	Idaho National Engineering Laboratory
IPT	Integrated Product Team
ICEG	Interagency Cost Estimating Group
ISU	*In Situ* Vitrification
IWTP	Industrial Wastewater Treatment Plant
Kb	KiloByte
LCC	Life-Cycle Cost
LLW	Low-Level Waste
MB	MegaByte
MCACES	Microcomputer-Aided Cost Engineering Support System
MDAP	Major Defense Acquisition Program
MRS	Monitored Retrievable Storage
ODC	Ozone-Depleting Compound
OU	Operable Unit

PC	Personal Computer
RA	Remedial Action
RAAS	Remedial Action Assessment System [model]
RACER	Remedial Action Cost Engineering and Requirements [model]
RAM	Random Access Memory
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RFI	RCRA Facility Investigation
RI	Remedial Investigation
SCEES	Superfund Cost Estimating Expert System
SCM	System Cost Model
SPO	System Program Office
SWMU	Solid Waste Management Unit
TASC	The Analytical Sciences Corporation
TRU	TRansUranic
UPB	Unit Price Book
USACE	U.S. Army Corps of Engineers
UST	Underground Storage Tank
VOC	Volatile Organic Compound
WBS	Work Breakdown Structure